TOWARDS THE PREVENTION OF WATER POLLUTION FROM INDUSTRIAL ACTIVITIES IN THE NAHR EL-KALB WATERSHED, LEBANON

RECYCLING FOR ACHIEVING CLEANER PRODUCTION IN THE SOLVENT USING INDUSTRY IN KESSRWAN

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Submitted in Partial Fulfillment of the Requirements for the Degree of Master inIntegrated Water Resources Management

Faculty of Graduate Studies
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January, 2011

Committee Decision

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Acknowledgement

I would like to thank my supervisors Dr. Sabine Schlüter and Dr. Abbas Al-Omari for their efforts and advice.

Furthermore, I would like to thank Dr. Armin Margane and the team of Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Lebanon for their support and help.

Special thanks I would like to address to Dr. Marc Sadeeh for his openness and the insight information he provided me about crucial key questions.

I highly acknowledge the German Academic Exchange Service (DAAD) for their financial support during the time of my studying in the bi-cultural master program Integrated Water Resources Management (IWRM).

Finally I would like to express my deepest appreciation to the numerous internal and external experts, who were always open for discussions and provided me with important background information.

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List of Abbreviations

ALI	Association Lebanese Industrialists
BGR	Bundesanstalt für Geologie und Resourcen
BOD	Biological Oxygen Demand
CCI	Chamber of Industry and Commerce
CDR	Council of Development and Reconstruction
CDR	Council for Development and Reconstruction
CIA	Central Intelligence Agency
COD	Chemical Oxygen Demand
CP	Cleaner Production
DALY	Disability Adjusted Life Years
DO	Dissolved Oxygen
EFL	Environmental Fund for Lebanon
EST	environmentally sound technologies
EU	European Union
GDP	Gross Domestic Product
GTZ	Gemeinschaft für technische Zusammenarbeit
GWP	Global Water Partnership
IRI	Industrial Research Institute
IWRM	Integrated Water Resource Management
LCPC	Lebanese Cleaner Production Center
MoA	Ministry of Agriculture
MoE	Ministry of Environment
MPH	Ministry of Public Health
MWR	Ministry of Water Resources
NEK	Nahr El-Kalb
NLRA	National Litani River Authoity

NOHSC	National Occupational Health and Safety Commission
O.E.B.	Office Des Eaux De Beyrouth
PER	Perchlorethylene
RECP	Resource Efficiency and Cleaner Production
SR	Solvent Recycling
SUI	Solvent Using Industries
TRI	Trichlorethylene
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
UNIDO	United Nations Industrial Development Organization
USAID	United States Agency for International Development
WWTP	Wastewater Treatment Plant
ZM	Zouk Mosbeh

List of Units

°C	Degree Celsius
$	US Dollar
ha	Hectare
km	Kilo Meter
l/s	Liter per Second
LBP	Lebanese Pounds
m^3/s	Cubic Meter per Second
mbar	Milli Bar
MCM	Million Cubic Meter
mm	Milli Meter

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Abstract

After regaining relative political stability, Lebanon´s industry is at a raise. In this context, solvent using industries (SUI) are, among others, expanding on a high rate without adequate waste management.
The conducted study attempts to serve the overall objective of preventing water pollution from SUIs within the Nahr El-Kalb (NEK) Watershed. Currently, used solvents are disposed of improperly and thereby polluting the environment, degrading quality of related water bodies as well as impacting the Mediterranean Sea. Thereto, industries of Printing & Packaging, Smaller Printing Presses, Paint Producers, Car Paint Shops, and Dry Cleaners have been identified as main actors, being predominantly located in the industrial zone of Zouk Mosbeh within the studied watershed.
To achieve the objective of this thesis used solvents, generated by local SUIs and their threats to the environment, have been identified.
Consequently, solvent recycling (SR) has been introduced within the concept of "Cleaner Production". The technology transfer of SR poses a win-win situation for industries and environment, since interests of individual companies are respected while negative environmental impacts are mitigated.
For assessing the willingness of local SUIs towards such environmentally sound technology a questionnaire has been conducted. Its results revealed that the vast majority of respondents are eager to participate in an external SR service. Additionally, the monthly amount of used solvents could be estimated at 12,515 liters. It further has been identified that industries of same branches use same solvents.
However, since probably not all branches of SUIs within the NEK Watershed have been considered, the actual volume of used solvents might be even higher.
Correspondently to the positive response, a service scheme for a recycling company has been established. In addition, benefits of SR for individual companies as well as possible advantages for the government and environment have been identified.
Finally, an exemplary business plan has been developed that depicts the profitability of such recycling service.

1. Introduction

1.1. Background

Any discussion held about topics related to Lebanon´s social, environmental or economic issues should be set into context of the country´s recent history and the tremendous challenges its people were facing throughout the last 35 years. These challenges started in 1975 with the outbreak of the civil war. It should last for more than 15 years and thereby resulted in social chaos and economic break down. During the period of 1964 to 1974 Lebanon experienced a stable growth of real output of 6%. With the outbreak of civil war a drop by -16.14 % in 1975, -57.14 % in 1976, and further -36.79 % in 1982 was recorded. Further substantial decline of economy was initiated by the end of the Lebanese central state authority in 1985, which gave way to an escalation of violence throughout the country. During this period, Lebanon lost around 200,000 people from its professional and skilled labor force (Eken, 1995). Further unstable times were marked with the withdrawal of Israeli troops in 2000 and of Syrian military in 2005. A major strike against the country´s prosperity and hence severe impacts on the economy was caused by the 33 days war in 2006. According to an UN report Israel destroyed 15,000 homes, 900 businesses, 77 bridges and 31 utility plants throughout Lebanon during that time and furthermore damaged all important main roads (IRIN, 2006).Lebanon´s largest power station was among the utility plants that have been damaged. Its destruction posed a firm strike against civil population as well as industrial activities (Symonds, 2006).

As violence in the country´s capital grew in the 1980´s, people started to move to safer areas. Unfortunately, this resulted in wild and unplanned settlements and establishment of industrial enterprises in the municipalities of Jounieh, Al Metn and Kessrwan (AVSI;

NDU, 2009). The weak or rather absent government of this time could not take hold on to this development.

Distribution networks and sewage systems were permanently target of adversarial attacks. One aim of this action was to weaken and sicken society deeply. Diseases spread fast since pathogenic germs could enter potable water supply system easily (Eken, 1995).

During the chaos of civil unrests, distribution and sewage systems did not get reconstructed sufficiently and new settlements have not been connected at all (El-Fadel, Zeinatia, & Jamali, 2001b). Furthermore during these troubled times, wastewater treatment plants got destroyed or could not operate properly. Operation of treatment plants was (and is until today) interrupted on high frequency due to the lack of electricity. The lack of sufficient electricity is to a great share result of the destruction of power stations (Sarraf, Larsen, & Owaygen, 2004).

In times of only little governmental regulations, partly out of no available alternative, partly out of nearly criminal intension and benefit maximization, hazardous and environmental polluting production procedures/practices had been adapted by industries in Lebanon (El-Fadel, Zeinati, El-Jisr, & Jamali, 2001a). Buried illegal dumping sites release pollutants to the soil until now (AVSI; NDU, 2009).

Furthermore, due to interrupted governmental water supply during war, people, including industries supplied themselves by private, unmonitored wells. This practice is partly in force to present.

However, now in times of relative political stability, national and international governmental organizations aim at reconstructing and developing infrastructure to overcome shortcomings of the troubled past (El-Fadel, Zeinatia, & Jamali, 2001b)

By the year of 2009 economic growth has returned to 8.6 % and current estimations state a real growth of GDP in 2010 by 7 %. Real growth of GDP is expected to stabilize at 6 % in 2011 (The Daily Star, 2010).

1.2. Problem Statement

Industries throughout the governorate of Kessrwan, especially in the industrial zone of Zouk Mosbeh, that is located close to the Nahr El-Kalb (NEK) Watershed´s outlet, contribute significantly to local surface and groundwater pollution as well as impacting marine life negatively (AVSI; NDU, 2009). Companies that contribute with hazardous waste to the water cycle are from the plastic processing sector, chemical and paper processing sector, mechanics, and other smaller industries (AVSI; NDU, 2009).This research evaluates specifically the share of the Printing & Packaging industry, Smaller Printing Presses, Paint Producers, Car Paint Shops, and Dry Cleaners.

Products of these industries are present in everybody´s daily life. Going to the supermarket, one might not find a single package that has not been printed on. Figure 1shows some examples of printed plastic films that are later processed to bags and containers.



Figure 1: Example of Printed Plastic Films, Source: (Amipak, 2005)

Car Paint Shops are omnipresent in Lebanon. Consequently, Paint Producers supply, among others, the vast industry Printing & Packaging as wells as the countless Car Paint Shops with their working materials. However, Dry Cleaners are frequently found as well and thus are meant to generate a considerable amount of liquid waste.

An impression of the dimension of liquid waste discharged by industries throughout Lebanon can be gained by the data provided in Table 1. The numbers given in the table are only estimations, since no records of actual quantities exist. Specific estimations for Kessrwan or even more specific the industrial zone of Zouk Mosbeh do not exist as well.

The impacts on health and environment resulting from the unregulated discharge of industrial wastewater are complex. Firstly, solvents that are used in the above mentioned industries are toxic from a relatively low concentration on. The solvents expected are for example: Ethyl Acetate, Isopropanol, Ethanol, Acetone, Perchlorethylene, and Methyl Ethyl Ketone (MEK). Secondly, while those solvents are degraded by bacteria, they contribute to an increase of the chemical oxygen demand (COD) in and of the biological oxygen demand (BOD) as well. This means that by discharging those pollutants to water bodies the dissolved oxygen (DO) might get declined and thus the quality of environment for waterborne life is reduced.

Table 1: Industrial Waste-Generation Estimates for Lebanon (1998)

Category	**Source/Type**	**Quantity (ton/year)**	**Remarks**
Hazardouswaste	Industrial waste containing heavy metals	1,166	From waste paper recycling, printing, ceramics industry(pigments), metal galvanizing, non-ferro metal recycling
	Industrial oilywaste	1,018	Residues from waste oil recycling, oily sludge, residues from solvents recycling
	Industrial paints, resins, dyes, adhesive residues	538	Mainly from paint, and wooden and metal productsmanufacturing
Total		**2,722**	

Source**: (Tebodin, 1998)**

Already in 1974 the Lebanese Government the Lebanese Government issued decree no. 8735, that regulates the disposal of wastewater from domestic, commercial and industrial sources. The decree prohibits the discharge of waste into any natural water body, including marine environment and deep well systems (Mallat, 1995). However, responsible authorities of the study area do not make sufficient use of this decree possibly expressed by water protecting measures. This is due to personnel and financial constraints (AVSI; NDU, 2009). Moreover, reflecting the country´s situation, Kessrwan lacks sufficient water and wastewater monitoring programs according to a statement of Dr. A. Margane, head of the BGR project towards the protection of the Jeita Spring in the NEK Watershed.

Institutional confusion among ministries hinders efficient water management rooting in overlapping and duplication in responsibilities and duties with other Lebanese governmental bodies. In some cases the Ministry of Environment (MoE) shares environmental management responsibility with eight other ministries and key institutions (El-Fadel, Zeinatia, & Jamali, 2001b).

Furthermore, inadequate funding and lack of proper management hinder authorities from fulfilling their duties. Consequently, not even preliminary effective water protecting actions can be set up (Masri, 1997).

Additionally to institutional constraints, the practical reality reveals that many domestic as well as industrial areas are not connected to the sewer system. Thus, industries of these unconnected areas discharge their untreated wastewater entirely uncontrolled either directly into canal systems that end up in the Mediterranean Sea, in rivers, or follow the strategy of wild dumping (Kronfol & Kaskas, 2007). The discharged wastewater partly contains great shares of used solvents and pigments.

1.3. Importance of the Study

During recent years, Lebanon gained political semi-stability. Therefore, the country became again attractive for investors. Consequently, significant economic and industrial growth in coming years is expected. Without the implementation of appropriate waste mitigation and prevention measures, industrial growth will inevitably lead to aggravation of environmental pollution.

Since industrial prosperity is seen as key factor to social stability, the Lebanese government lays priority on providing attractive conditions for investments like low or up to no taxation and only marginal regulations. In this course, for the sake of industrial prosperity implementation of existing environmental decrees and laws is not intended, since their compliance is associated with extra costs for the individual company (Sarraf, Larsen, & Owaygen, 2004).

Currently, the feasibility study for a wastewater treatment plant (WWTP) in the study area is under preparation. The input of contaminants will determine the design of this WWTP. Thus, the findings of the prepared study and the intended prevention of pollutants entering the water cycle can have a direct consequence on future water management. Pollution prevention can reduce investment costs for the WWTP and thereby free capacities that could be invested in additional facilities.

Increasing water demand and climate change lead to increased water stress throughout Lebanon (Karam, 2002). Thereby, the country´s water budged could experience a severe water deficit soon (El-Fadel, Zeinati, & Jamali, 2000a). This makes the protection of the remaining resources out most important.

1.4. Objectives

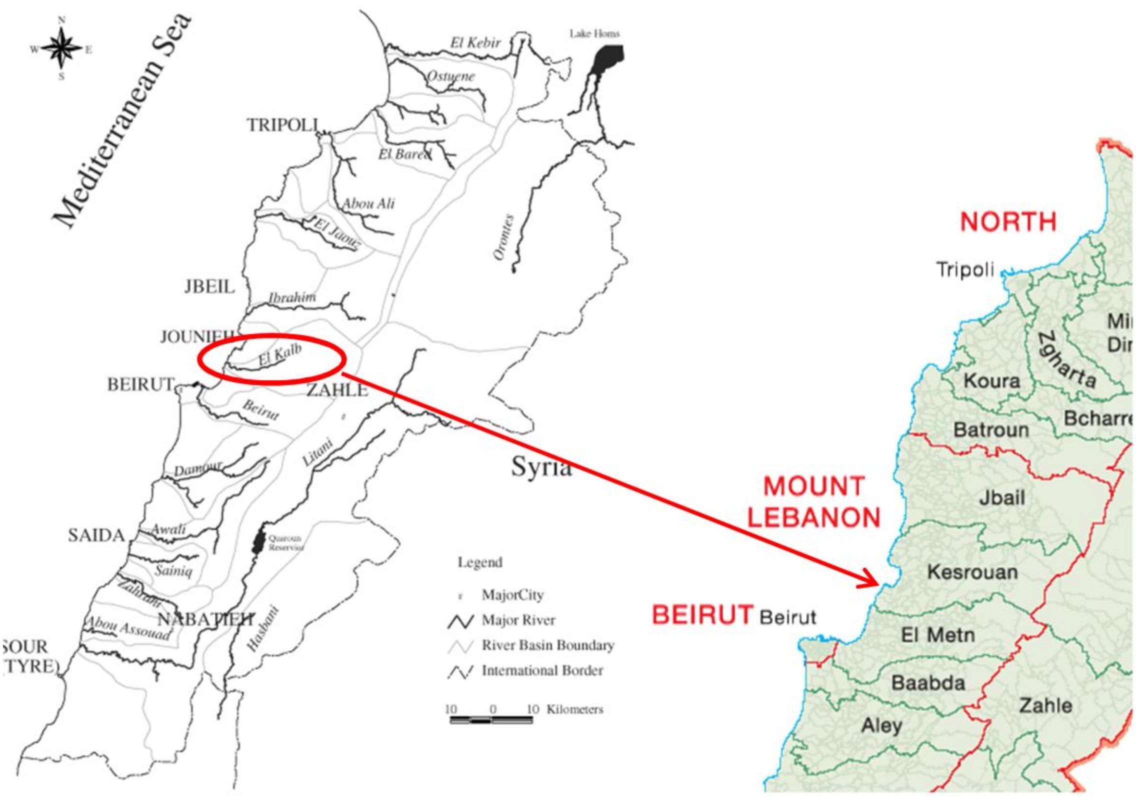
The long term aim is to protect water bodies of the governorate Kessrwan within the Nahr El-Kalb Watershed from pollution caused by solvents and components in solution released by local industries. With increased industrial activities, proportionally increased amount of discharged contaminants is expected. Consequently, options of "Cleaner Production" must be evaluated to mitigate the latter.

The objective of this thesis is to assess the potential environmental, economic and social consequences from impacts of solvent using industries (SUI)s in the NEK Watershed while taking its physical set up and environment into consideration. It furthermore respects the socio economic status of this basin in addition to the institutional and legislative framework.

2. Study Area

In the proposed research the governorate of Kessrwan within the Nahr El-Kalb (NEK) Watershed shall be examined exemplarily for the region of Mount Lebanon. As Map 1 shows, the chosen watershed lays around 20 km southerly to Lebanon´s capital Beirut. The NEK Watershed covers a total area of 264 km², equally shared by the two governorates of Kessrwan and Al Metn. Currently, Kessrwan is inhabited by about 191,600 people and Al Metn by about 150,700 (AVSI; NDU, 2009). It is expected that the population will increase further within short time, since an extraordinary number of domestic buildings are currently under construction.

Within this area, most potential sources of pollution are found in the industrial zone of Zouk Mosbeh. Further minor industries are scattered within the remaining municipalities of the watershed.



Map 1: River Basins of Lebanon with Illustration of Nahr El-Kalb and Study Area Kessrwan (Kesrouan)

2.1. Natural Conditions in the NEK Watershed

2.1.1. Geology of the NEK Watershed

Understanding the geology and soil characteristics of the study area is essential for assessing the vulnerability of the hydrological system and the probable impacts of pollutants reaching it. Pollutants enter underlying water bodies by infiltrating into the soil. Depending on the soil density, and the presence of faults and cracks in addition to other factors, the retention time of pollutants in the soil can be estimated. The shorter the retention time is, the greater are impacts of pollutants on groundwater quality.

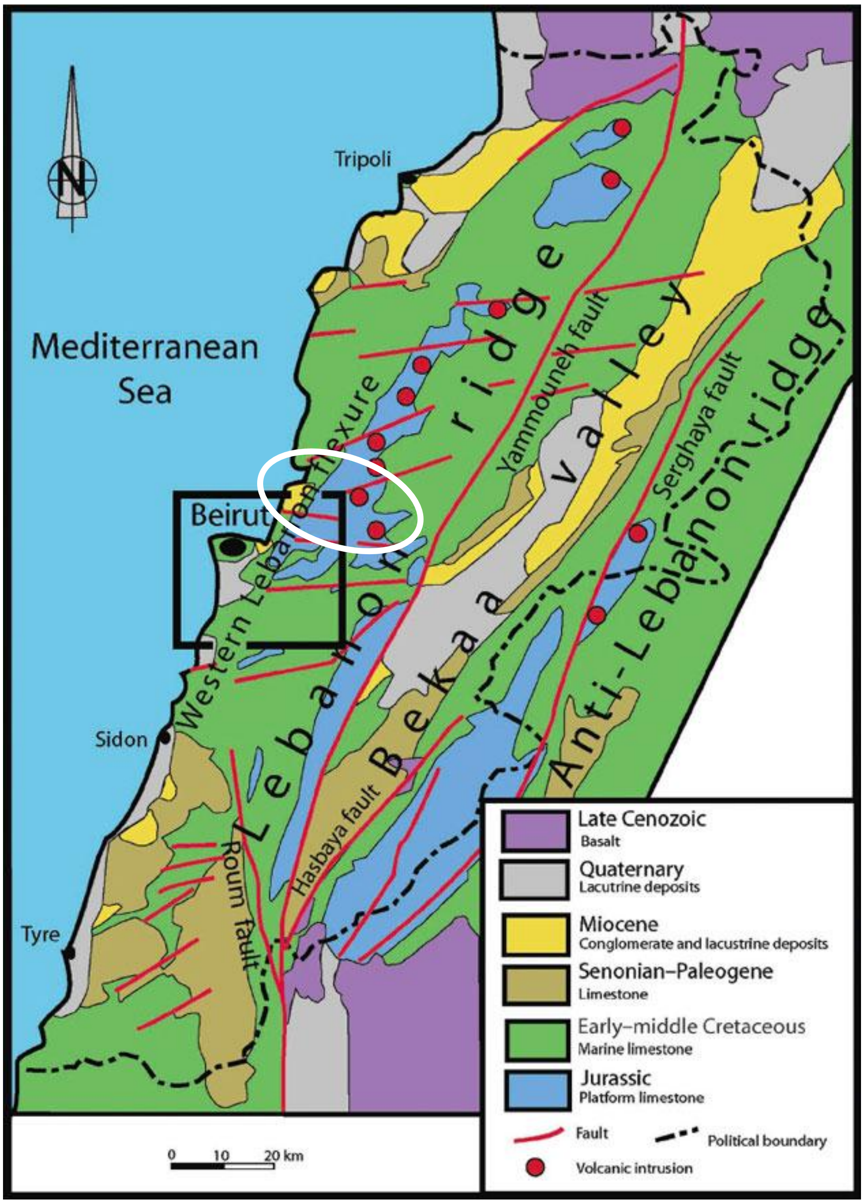
The NEK Watershed consists of three geological layers from different historical times. At different spots, different thicknesses of these layers are found. Additionally, due to tectonic activities, traces from different historical periods can be found intermixed. Limestone is predominant in the watershed which leads to a highly karstic soil structure within the watershed. However, in the high mountainous regions volcanic intrusions in form of basaltic and ash tuffs have further been found.

As shown in Map 2 the soil layers in the NEK Watershed predominantly consist of Jurassic limestone. Towards the coastal area a layer linked to the early middle Cretaceous period is found. This layer consists of marine limestone. The actual coastal zone hosts a layer from the Miocene times, which consists of conglomerates and lacustrine deposits.

Furthermore, the map shows the three major faults in the watershed. The first, the Ajaltoun fault in the North is characterized by vertical as well as horizontal throws. The horizontal throw causes a displacement of about 100 m. Located in the center of the watershed, the Ballouneh fault with its East-West trend plays an important role for the Jeita spring. This fault is associated with the Jeita cave system and thus meant to feed the spring that is source of potable water for greater Beirut. Like the Ajaltoun fault, the Ballouneh fault shows a horizontal displacement of about 100 m. As third of the

important throws the Office Des Eaux De Beyrouth (O.E.B.) fault is to mention. It owns a horizontal displacement of about 2 km.

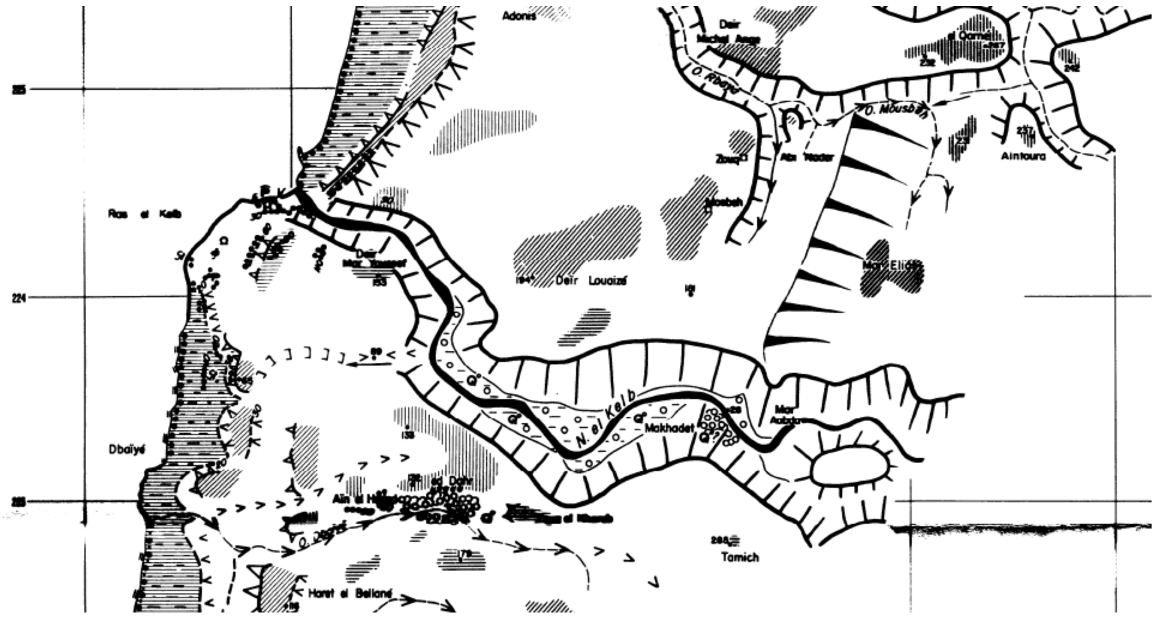
Furthermore, a number of minor cross trending faults dissect the entire area of the NEK Watershed.



Map 2: Simplified geological map of Lebanon. Study area marked in white circle (modified from Dubertret, 1955, 1975, in Walley, 1998).

As the NEK Watershed is rich in its variety of layers and faults, it likewise has to offer extreme differences in the surface structure. As seen on Map 3, the watershed provides steep slopes of up to 75° close to the river bed. Areas of the Jurassic plateau in the higher regions are characterized by dips varying from 5° to 15°. The areas rather

oriented to the West offer dips of more than 25°.Within the riverbed itself slopes of 12° to 20° are found. While at the coastal zone the structure only offers a tendency towards West (Sanlaville, 1977).



Map 3: Geomorphology of the NEK Watershed (Sanlaville, 1977)

Outcome

The present steep slopes, canyons and faults in the watershed lead to canalization of runoff. Thus, the retention time of precipitation and pollutants that are potentially carried with by the flow is very small and reaches surface and underground waters very quickly.

The karstic nature of the limestone and the accompanying natural underground channels lead to a very low self-purification of water. In heavy soils bacteria usually have enough time to stabilize pollutants before they can reach water bodies. As the limestone offers very high infiltration rate, retention time is not enough to stabilize pollutants. Due to the high permeability of the watershed´s soil, pollutants that enter the soil find their way additionally via cracks and various faults into the underlying water bodies. For the less

permeable areas of marble and intact rock, pollutants are trapped at the soil surface and have a direct impact on the environment (O.E.B., 1971).

2.1.2. Hydrology

2.1.2.1. Climate

The Nahr El-Kalb Watershed is generally characterized by an Eastern Mediterranean climate that offers moderately cold and rainy winters and hot and dry summers. As the watershed stretches throughout an altitude of between 0 and 950 m, seasonal variations in the climate are observed. Representative for the different heights are the weather stations of Zouk Mkayel, Quornet Chahouane, and Bikfaya, as shown in Table 2. The first weather station is located in the coastal zone of the watershed. It can report an average temperature of 21.3 °C and an average annual precipitation of 901 mm. On average, humidity in the coastal zone lies at about 70 % (El-Fadel, Zeinatia, & Jamali, 2001b). Climatic data for this location was collected over a period of 28 years prior to the 1975 civil war. However, it does not reflect weather alterations induced by climate change. Unfortunately, the data presented in Table2, published in 1988 is the most recent data available for the three weather stations and throughout the entire watershed. Located at an altitude of 603 m, the Quornet Chahouane weather station recorded over a period of 5 years an average temperature of 18.3 °C, while the mean annual precipitation is 1050 mm. Heading towards the highest spot of the watershed, Bikfaya located at an altitude of 903 m has an average temperature of 15.3 °C and an annual mean precipitation of 1336 mm.

The climatic conditions make the NEK watershed suitable for agriculture and attract people who seek relief from the summer heat due to its moderate temperatures. Furthermore, the predominant wind direction at day time is from the coastal zone towards the mountainous area which is West-South-West to North-North-East which

fosters precipitation in winter and fresh air in summer. At night East-West wind dominates which blows from the mountainous region towards the coastal zone.

Table 2: Average monthly and yearly precipitations and Temperature of the Nahr El-Kalb Watershed

	Zouk Mkayel		Quornet Chahouane		Bikfaya	
Altitude	70 m		603 m		900 m	
	Prec. (mm)	T (°C)	Prec. (mm)	T (°C)	Prec. (mm)	T (°C)
September	9	27.1	10	23.1	14	20.2
October	43	24.1	50	21.3	61	17.7
November	111	20.1	117	16.6	127	13.2
December	170	16.3	182	13.1	249	9.5
January	217	14.4	217	11.1	294	7.1
February	155	14.4	199	11.4	250	7.7
March	123	15.9	155	13.2	210	10.3
April	49	18.8	90	16.5	91	14.3
May	22	22.2	27	20.3	37	17.9
June	1	25.7	2	23.7	2	20.9
July	0.5	27.9	0.5	24.7	0.5	22.1
August	0.5	28.6	0.5	24.8	0.5	22.4
Average in mm/year	901		1050		1336	
Average Temperature		21.3		18.3		15.3
Number of years	28		5		22	

2.1.2.2. Discharges: Springs and Wells

The NEK Watershed hosts the main river El-Kalb and several Wadis that are contributing to it. The average flow of the River El-Kalb is estimated at 8.56 m^3/s at the Mokhada station.

The river starts at an elevation of 1,300 m where steep slopes of 18 to 60% of the riparian canyons direct the runoff to the river. Furthermore, infiltration plays an important role in this section. The next section of middle runoff is characterized by impervious layers where water that infiltrated in the higher runoff section is forced to

the surface and results in various minor springs. This zone is considered to be the main collector of the Nahr El-Kalb.

Surface and spring water supplement the river towards the valleys. Further impervious layers result in major springs like Jeita and Qachqouch (AVSI; NDU, 2009).

The watershed hosts four permanent springs that are illustrated in Table 3. Jeita spring is by far the source of the highest amount of freshwater. After light treatment, water originating from there is supplying about 1,200,000 people in the area of greater Beirut.

The watershed´s annual total hydrological yield is estimated at a minimum of 120 $x10^6m^3$ and on average 200 $x10^6m^3$ (Hamiyeh, 1974).

Table 3: The four permanent springs of the NEK basin with their elevations and discharges

Spring	Elevation [m]	Discharge	
		Minimum Year [$x10^6m^3$]	Average Year [$x10^6m^3$]
Jeita	141	68	83
Nabaal El Assal	1,500	23	30
Nabaa El Laban	1,600	9	23
Qachqouch	96	15	25

Source: (Hamiyeh, 1974)

Despite the age of this data, no up-to-date data is available for this research. However, Figure 2indicates the general trend of the depletion of all major springs during the time period of 1965 and 1999 throughout Lebanon. Amongst these major springs Jeita is also mentioned. Although the single springs cannot clearly be identified, yet not a single spring has kept its yield or has increased. Furthermore, due to political unrests during this 25 year time period, data records are not complete. Still it can be seen that some of the elaborated springs decreased in their discharge by up to 60 % (LRA, 2006).

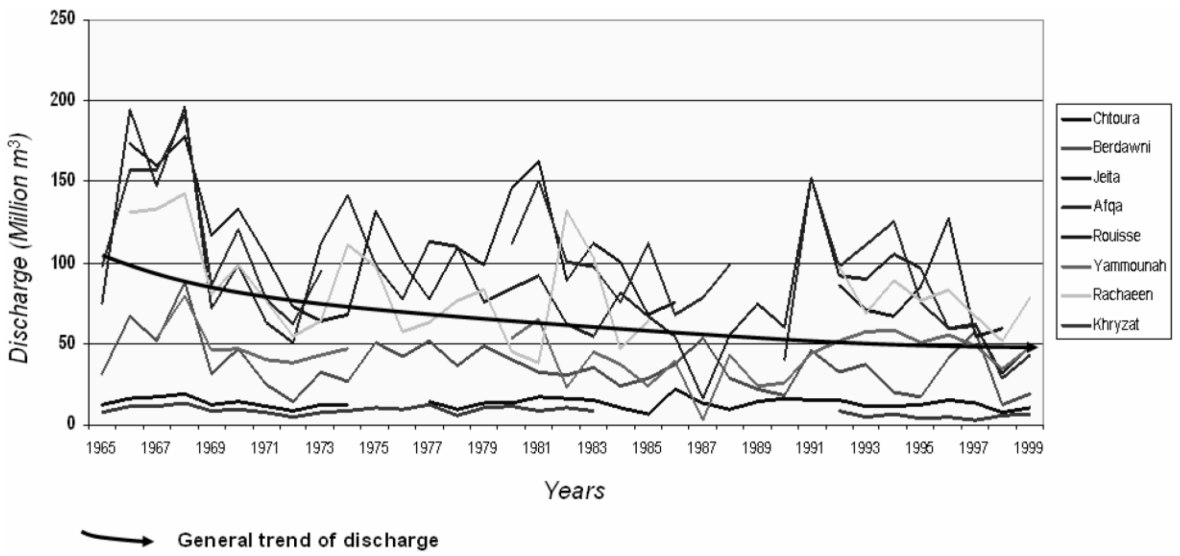


Figure 2: Discharge from major Lebanese springs between 1965 and 1999

Source: (LRA, 2006)

Shaban connects this development to the impacts of climate change on the water balance of Lebanon (2006). He intends to proof this statement by the decrease of precipitation throughout Lebanon by the year of 2006 of 12 % compared to the year 1965. However, it is unlikely that a potential decrease of recharge by 12 % is followed by spring depletion of up to 60 %. The depletion of the springs is rather referred to the increase of groundwater abstraction from wells that usually would contribute to the springs discharge. As Table 4 clearly states, the consumption per capita increased within the last 100 years by roughly 25 %. Furthermore, population growth contributed additionally to the depletion of groundwater.

Table 4: Development of domestic water needs in Lebanon

Year	Average Consumption rate [l/d]	Total dialy needs [m^3/d]	Annual needs [MCM]
1900	165	850,000	310
2000	215	1,500,000	550
2015	260	2,500,000	900

Source: (Kronfol & Kaskas, 2007)

As Lebanese water right states that landowners are entitled to abstract underlying groundwater, reliable estimations of the actual groundwater abstraction are hard to undertake. Since quantities of abstraction are not restricted, no real control for keeping a safe yield can be performed (Kronfol & Kaskas, 2007).

Besides the increase of domestic consumption, an increased water demand from the agricultural sector plays a significant role for the water balance of the NEK Watershed. Throughout Lebanon an increase of demand in this sector is estimated from 750 MCM to 1200 MCM between the years of 1995 and 2000. Since agriculture is present in the basin to a significant share, this development might have also affected the NEK and the springs´ discharge within the basin.

Numerous wells drilled in the watershed affecting the NEK do further deplete the groundwater level. In Table 5 governmental wells are shown that are having a negative impacts on the groundwater level and thus the flow of the NEK. However, the data is relatively old. As illustrated before, every landowner is entitled to abstract groundwater from his land on a rate of his desire. Thus, Table 5 might give a hint on the groundwater abstraction in the NEK basin, but is by nature far away from the actual situation since it is only representing governmental wells and no private, uncontrolled.

Table 5: The wells drilled in the vicinity of the Jeita spring and their respective depths and discharges

Well	Depth (meters)	Discharge (Liters/s)
F1	250	30.76 at 20 meters depth
F2	350	Salty water
F4	25	30.76 at 12 meters depth
F5	140	1.5
F6	21	8
F7	20	40
F8	20	40

Source: (Saadeh, 1994)

2.1.3. Hydrogeology

As mentioned earlier, the soil of the NEK Watershed is highly karstified and offers an abundant number of faults. This finds its extreme expression in the underground river feeding Jeita Grotto. The system of Jeita´s channels and caves stretches over a distance of 6.2 km. Furthermore it is fed by a connected aquifer with an average annual, flow of 5500 l/s.

The interaction of highly permeable Jurassic limestone and impermeable Cretaceous layers finds its expression in the Qachqouch Spring. The average annual flow from the connected aquifer system is 800 l/s (Hakim, 1975).

The present fault and micro-faults of the NEK basin combined with the permeable Jurassic limestone and karstified soil lead to a rapid surface infiltration. High infiltration rate and lower impermeable soil layers lead to numerous seasonal springs that outburst during winter throughout the watershed. However, the high infiltration rate also results in low natural purification of runoff. Moreover, any pollutant entering the soil, reaches the underlying water body within hours.

The extremely short retention time of pollutants was documented while researching on an appropriate location for a wastewater treatment plant in the basin. According to Dr. A. Margane, colorants were injected to the soil at the beginning of the Jeita channel and caving system. Only 48 hours later, first traces of the colorants were found in the Jeita Grotto located 6.2 km downstream.

2.2. Influences on Water Quality in the NEK Watershed

2.2.1. Current and Expected Water Resources Availability in Lebanon

The documentation of water resources throughout Lebanon and in specific the NEK Watershed lack substantial data. Thus, the following paragraphs mostly evaluate on the situation of the entire country and conclude where possible for the NEK Watershed.

Water Balance

No reliable and consistent climate records are available for the NEK Watershed or even Lebanon. Thereby, giving accurate numbers of the current water balance throughout Lebanon is a challenging task.

Table 6 gives information about estimated annual average in and out flows of Lebanon´s water budget. Precipitation is estimated at 8,600 MCM annually. As basic data sets are missing, losses of this due to evaporation are estimated (and not measured) at around 50 %. In addition, surface water that flows into neighboring countries accounts for a further budget reduction of approx. 670 MCM. Groundwater that is not exploitable or lost to the Mediterranean Sea or to neighboring countries is assumed to account for additional 1,030 MCM. Consequently, if subtracting all water losses from the stated precipitation, an amount of available net potential surface and groundwater results in 2,600 MCM annually. However, out of this an actual amount of 2,000 MCM per year is feasibly exploitable and thus ready to use (El-Fadel, Zeinati, & Jamali, 2000a).

Table 6: Annual Water Balance of Lebanon

Description	Yearly average flows [MCM]	
Precipitation		8,600
Surface water evaporation losses (assumed to be 50% of precipitation)		-4,300
Surface water flows to neighboring countries		
El Assi (Orontes) River	-415	
El-Kebir River	-95	
Hasbani River	-160	
Subtotal	-670	-670
Groundwater flow		
Unexploitable groundwater or losses to the sea	-880	
Losses to neighboring countries	-150	
Subtotal	-1,030	-1,030
Net potential surface and groundwater available		2,600
Net exploitable surface and groundwater		2,000

Source: (El-Fadel, Zeinati, & Jamali, 2000)

Climate Change

Lebanon receives 35% of all precipitation in form of snow. This is the ideal form of water storage, since in the frozen phase nearly no losses due to evaporation or runoff occur. In the context of climate change a temperature increase within the next 50 years for Lebanon of 2°C to 4°C is expected (Karam, 2002). Predictions from different sources vary significantly from each other, and so far no clear traces of weather modification could be identified for Lebanon (Saadeh D. M., 2010). However, an increase of 2 °C could lead to the shifting of the snowline from 1,500 m to 1,700 m throughout the country. The loss of 200 m snowline could result in a reduction of snow by 42% (Karam, 2002) and thus into a severe cut down in Lebanon´s water budget. Snow, that provides many regions in some years as long as August with melt flow would no longer be a reliable source of fresh water.

Water Demand by Sector

Domestic

The forecast of demands by sector depend on numerous information. For the domestic sector the factors of number of population, per capita use, population growth and economic situation of users are crucial (El-Fadel, Zeinati, & Jamali, 2000).

During the times of civil war Lebanon experienced a huge wave of emigration to countries, what impacted population growth significantly (El-Fadel, Zeinati, & Jamali, 2000). Thus, classical population growth is not present in Lebanon, which leads to estimations of present and future total population that differs significantly from each other. Table 7and Figure 3 illustrate different estimations of current total population and its development. While Jaber estimates in 1993 the population for three years back at 5.2 Mio, the International Monetary Fund depicted a population for the same year of 2.9 Mio. While Dar Al Handash predicted for 2010 5.88 Mio inhabitants in Lebanon, the CIA Factbook assessed their number in July 2010 at about 4 Mio. These extreme variations inevitably result in conflicting projections of future water demands, since the correct prediction of domestic water demand highly depends on the precise number of total population. It is the sum of the latter x per capita consumption.

Table 7: Different estimations of current and future total population of Lebanon

	Population in millions						
Year	Jaber (1993, 1996)	Al Hajjar (1994, 1997)	Khatib&Alami (1994)	ERM (1995)	Dar Al Handash (1998)	ESCWA (1999)	Amhaz et al. (1992)
1990	5.2	5.0			> 4.0	3.0	
1995				3.7			4.0
2000	7.1	6	4.4	4.2	4.70	3.6	4.37
2010		7.4	5.6	5.0	5.88	4.1	5.53
2015	9.1			5.8			
2020		9	7.1		7.36	4.7	
2030			8.5				8.96

Source: (El-Fadel, Zeinati, & Jamali, 2000a)

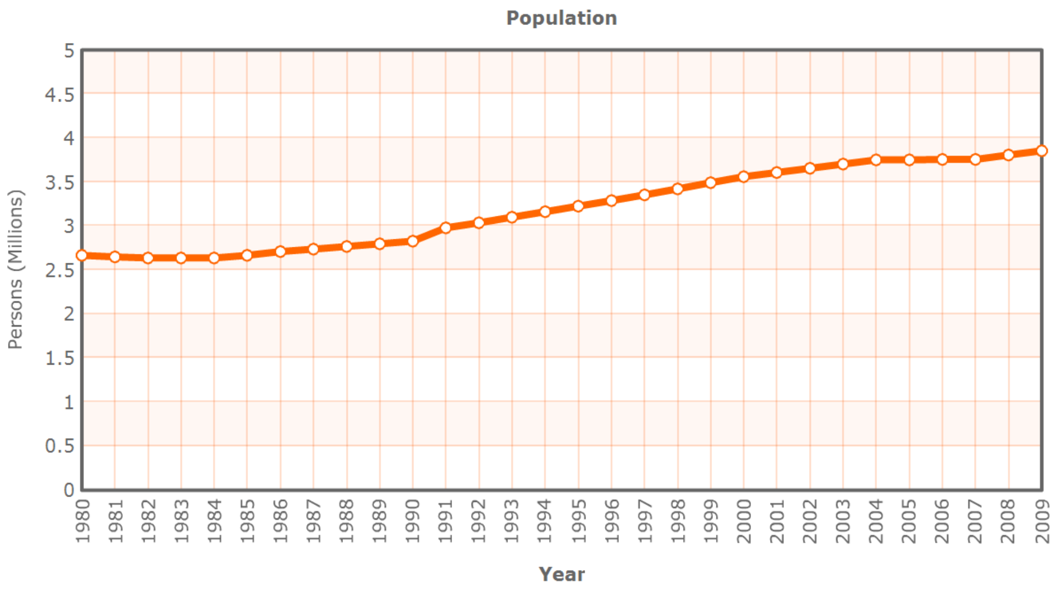


Figure 3: Population development of Lebanon estimated each year for the current year
Source: International Monetary Fund – 2009 World Economic Outlook

Even though the country experiences currently political relatively stable times, emigration of people continues. Especially young people are forced to leave the country out of educational and economic reasons for good.

The withdrawals of Syrian military from Lebanon lead further to immigration of thousands of Syrian workers from Lebanon in 2005. It is estimated that in this year about 250,000 Syrian people left Lebanon. Consequently, the country´s water demand and balance had to be redefined once again with the decrease of consumers.

Table 8illustrates the water demand development based on a population of 4.5 Mio in the year 2000 and an estimated growth rate of 2 %. Furthermore, a daily consumption rate of 190 L/capita x day with an increase rate of 1.75 % is assumed. Although these numbers might not reflect absolutely the present and future situation, it still indicates the threat of severe water deficits throughout the country in the near future if no proper mitigation measures will be taken.

Industry

Similar to the domestic sector, no precise data for the industrial sector is available. A big share of industries are not located within the established industrial zones, nor even registered. Hence, no concrete numbers but only estimations are existent regarding their number, location and size.

Undoubtedly, the industry´s prosperity was decelerated by the civil unrests and political instabilities of the past. Under these anarchic conditions, dubious practices regarding water self-supply had been fostered. Hence, as a bequest of this time, industries still abstract their water to a big share from private groundwater wells. Consequently, the numbers illustrated in Table 8 state only a fraction of the actual water consumed by the industry (Jaber, 1993).

However, industries are expected to grow throughout the next year at an annual rate of 3 %. Metered water consumption is expected to increase proportionally (El-Fadel, Zeinati, & Jamali, 2000).

Table 8: Development of Water Demand in Lebanon by Sector

Year	Domestic [MCM]	Industrial [MCM]	Irrigation [MCM]	Total [MCM]
2000	312	205	870	1,387
2010	452	445	1,000	1,897
2015	532	516	1,200	2,248
2020	641	598	1,350	2,589
2025	780	693	1,500	2,973
2030	876	804	1,600	3,280

Source: (El-Fadel, Zeinati, & Jamali, 2000)

Agriculture

As population grows, demand for agricultural products increases proportionally. Thus, areas currently under irrigation must be extended which leads, without mitigation measures, to a proportional increase of water demand. Besides the aspect of aimed semi self-sufficiency, increased export of agricultural goods might lead to an expansion of

cultivated and irrigated land. As shown in Table 8 this increase could actually lead to a doubling of demand by 2030 compared to the year 2000.

Water Deficit

From the available water as stated in Table 6and the growing demand of the single sectors of Table 8 the concluding Figure 4 can be drawn. It indicates that Lebanon has to face true water deficits at the estimated development by the year of 2011. The level of exploitable water does not acknowledge eventually reduced groundwater recharge due to climate change and thus stays constant for the entire shown time period. Nevertheless, according to this figure, water deficits reach approximately 1200 MCM annually by the year 2030.

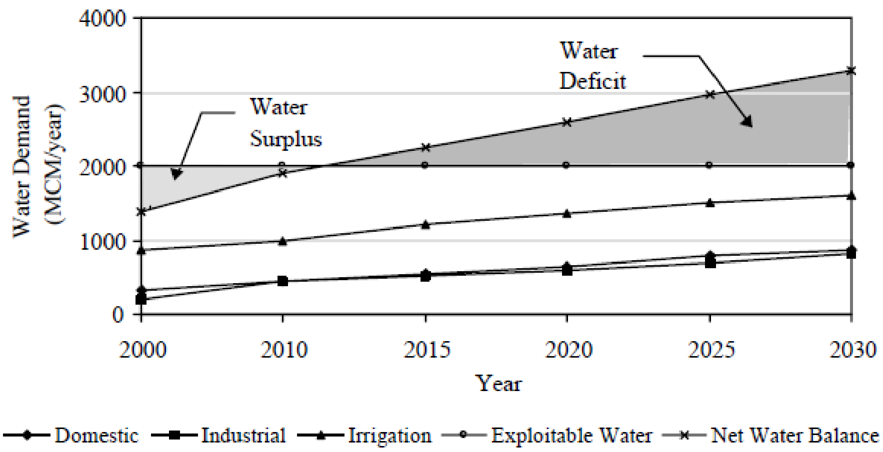


Figure 4: Development of Water Demands by Sector in Lebanon compared to Water Availability

Source: (El-Fadel, Zeinatia, & Jamali, 2001b)

As further seen in the Figure 4, irrigation requirements alone nearly consume all available water if trends continue without mitigation.

Outcome

Water losses due to increased temperatures and thereby decreased share of snow of precipitation is not considered in Table 6 and Figure 4. Furthermore, the assumed

evaporation rate of 50 % seems to be too low compared to those of neighboring countries.

Resulting from these two factors, the water deficit shown in Figure 4 might even be extremer and more severe at earlier stage.

As it can be seen in Table 8, agriculture expressed in irrigation is by far the biggest consumer. Although its relative share reduces over time mitigation measures in this sector must be priority.

If the consequences of increased water demand shall be mitigated, governmental actions must be taken to reduce demands in the single sectors. Common instruments throughout neighboring countries are the reduction of irrigation demand and thereby the increase of water efficiency. This is achieved by actions like the use of reclaimed water or the introduction of drip irrigation.

Additionally, the industrial sector must acknowledge its responsibility towards environment and society. The re-use of water and recycling wastewater might be key factors in this process. However, this adaptation needs strong involvement of the responsible governmental institutions.

As stated in chapter 2.2.2, the leakage rate of the distribution network in the NEK Watershed is high. Unfortunately, this applies for the entire country. As stated by a consultant of the Litani River Authority, Dr. M. Saadeh, leakage rate of greater Beirut e.g. is estimated at 60% which led to the mitigation method of limiting water supply to 10 hours per day.

Finally it can be stated that the water situation of Lebanon is severe but not hopeless. Firm actions must be taken very soon to restore the balance between water availability and demand.

2.2.2. Water Supply in the Study Area

The clarification of water supply in the study area is of special interest. The management and condition of a distribution network provide significant information of possible impacts of pollutants entering the soil and thus eventually getting into contact with the distribution system of potable water. In case of interrupted water supply contaminants can enter easily the damaged distribution network and thus affect directly the health of consumers. This originates from the negative pressure that occurs while water pressure is decreasing within the pipe with interrupted of supply. Consequently, solved materials and chemicals can enter the system from its surrounding environment.

Information used for illustrating supply practices in the governorate of Kessrwan had been collected at the municipality of Shaile. Accordingly, the water supply strategy in this municipality is shared by all districts throughout the entire basin.

Distribution Scheduling

No specific distribution scheduling is in force in the researched basin. At the time of the research conduction, November 2010, water was supplied once to twice per week. During nighttime households received potable water for up to three hours. For overcoming the distribution lacks, each household has a water tank of individual size. Each household pays a yearly lump sum and is thereby theoretically entitled to receive 1 m^3 daily. However, due to the current distribution practice, this amount is never reached. Moreover, if the water distributed by the government is not sufficient for the individual household, recipients must provide themselves with water privately.

Continuous water supply is not achieved during any time of the year. According to the head of the local water treatment plant Dr. P. Souaid, this might be caused by a water deficit in the basin´s budget. However, even if the available quantity would be sufficient for continuous supply, electrical blackouts would still cause interruptions. Local

distribution facilities do not have backup generators to supply themselves with the required electricity (El-Fadel, Zeinatia, & Jamali, 2001b).

Distribution Network

Main pipes obtain a diameter of approximately 200 mm. However, due to uncontrolled building constructions, these mainlines are not sufficient and thus many households are tentatively connected to the network by a number of small pipes with a diameter of approximately 50 mm. Consequently, water pressure losses resulting from the decreased pipe diameter and increased friction rate lead to a lower quality of water supply.

Additionally to design constraints, the distribution network is damaged at many spots. Partly, this is still a bequest from the civil war, but partly it is the result of poor installation of new lines. As the damage rate in the network is high, seepages and thus water losses are proportional. Hence, a roughly estimated leakage rate of 50 % can be stated. At some spots leakage rate is actually that high that water finds its way through the asphalt of streets.

As mentioned, the interaction of interrupted water supply and damaged pipes lead to a very high possibility of contamination with pollutants that are introduced to the soil surrounding the distribution network.

Sources of Water

The source of water distributed by the governmental side is usually the Naber al Labbane Spring in the region of Faraya. At the time of the research conduction the supply from this source had been interrupted for more than one week.

According to the director of the responsible water treatment plant, this incidence was connected to an insufficient storage quantity of water collected in the Chabrouh Dam that is fed by the mentioned spring.

If households must arrange for additional water, they have to buy water from nearby private wells.

Water Monitoring

As for the distributed water from governmental side, water quality monitoring is performed according to the Lebanese standards set by LIBNOR (see Annex III).Nonetheless, depending on available resources, these tests are performed on daily basis.

However, neither monitoring, nor standards are applied for assuring the safe consumption of water originating from private wells. Experts like Dr. P. Souaid confirm that, taking the karstic nature of the basin´s soil, the presence of countless uncontrolled septic tanks and uncontrolled liquid and solid waste disposal into consideration, water from private wells poses a real threat to consumers.

2.2.3. Land and Water Use

Land use in the Nahr El-Kalb Watershed is divided into the four categories of domestic, industrial, agricultural, and forestry areas. Forests depend solely on precipitation; therefore the accounted water use differentiates only between the classical three categories of domestic, industrial, and agricultural water consumption.

The NEK Watershed is divided into five different zones. They are assorted according to their elevation as shown in Figure 5. In each respective zone the sectors of domestic, industrial, and agricultural land use are represented at different shares.

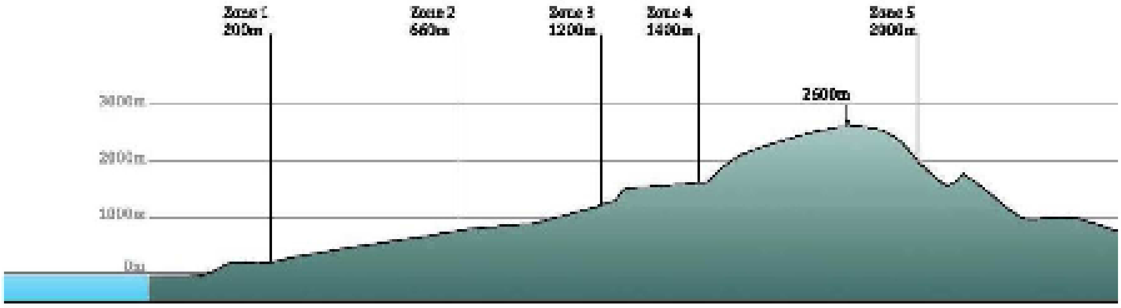
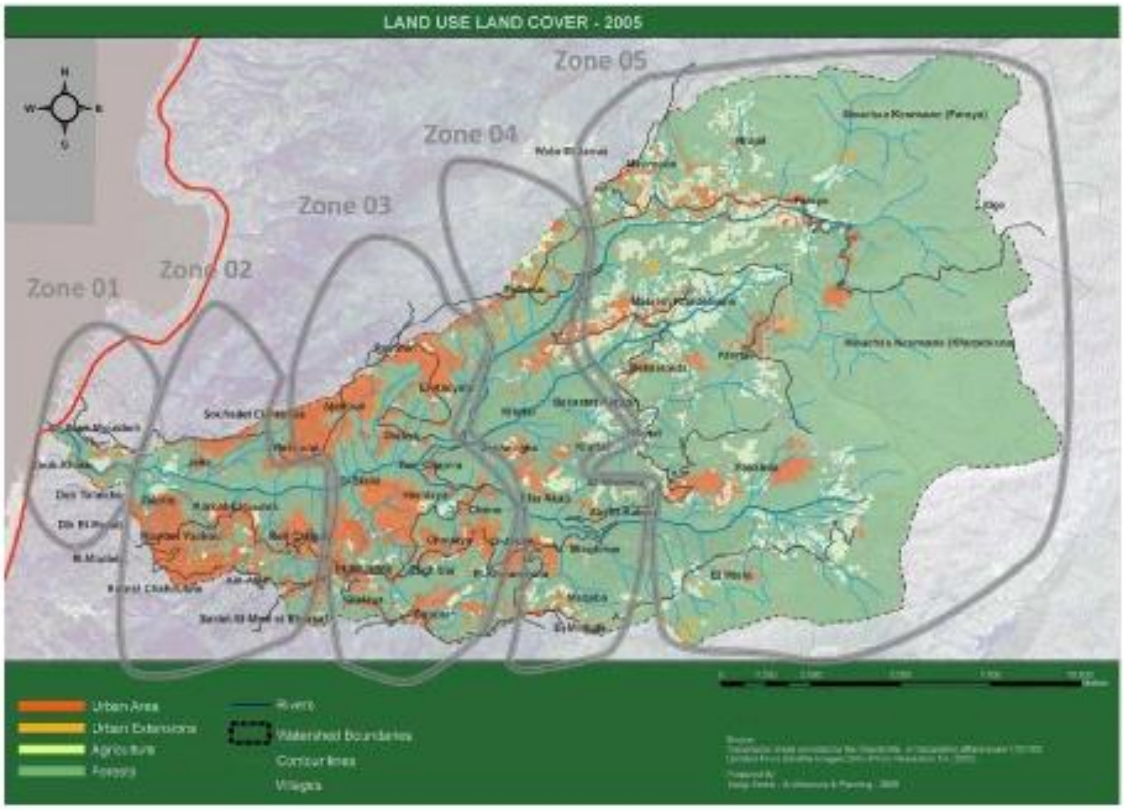


Figure 5: Different Zones in the Nahr El-Kalb Watershed according to the elevation

Source: (AVSI; NDU, 2009)



Map 4: Land Use and Land Cover in the Five Different Zones of the Nahr El-Kalb Watershed
Source: (AVSI; NDU, 2009)

Table 9 elaborates on the characterization of the different zones in terms of urban fabric density the existence of quarries in the area, the city character, established tourist resorts, and other possible attractions. The description is further illustrated by Map 4 that clarifies certain land uses by marking them in different colors. Additionally the map

shows that the assembled numbers do not refer strictly to the hydrological watershed but rather to the context of the administrative districts.

Currently industrial activities are most dense at the coastal zone and become less dense with further distance to the Jounieh Highway, main road of transportation which marked as red in Map 4. Unfortunately, the source of this map does not differentiate between producing industry and reselling businesses. From field visits it is known that in Zone 3, the low villages, nearly no industry exists at all. Even in Zone 2 it is hard to find any shops but galleries for domestic needs. According to information collected at the municipality of Jeita, first establishments of producing industries can be witnessed in the area of Shaileh, a municipality further up the watershed. The industry that Table 9 is referring to in Zone4 and Zone5 mainly describes existing quarries. However, it is not known whether the authors of these numbers relate to tourist resorts and areas for skiing as tourist industry.

Table 9: Classification of the Five Different Zones in the Nahr El-Kalb Watershed

	Zone 1 Coastal Zone	Zone2 Rear Country	Zone3 Low Villages	Zone4 Rural Area	Zone5 High Mountain
Urban Fabric Density	Dense	Medium & Dense	Medium	Low	Low
Quarries	No	No	Yes	Yes	Yes
City Character	Proximity to Main Urban Poles	Proximity to Main Urban Poles	Summer Village	Summer Village	Little Residential Area
Tourist Resorts	No	No	Yes	Yes	Yes
Attractions	Archeological sites	Universities & Schools	XXX	Archeological Sites	Ski Resort, Archeological Sites

Source: (AVSI; NDU, 2009)

Different estimations on the size of cultivated and furthermore irrigated agricultural land in Lebanon exist. For this research it is assumed, based on the average of estimations of several sources, that the total cultivated land amounts to 300,000 ha, out of which 68,000 ha are supposed to be irrigated. In other terms, roughly a quarter of all cultivated land is irrigated (El-Fadel, Zeinati, & Jamali, Water Resources in Lebanon: Characterization, Water Balance and Constraints, 2000). This estimation is the basis for the calculations of Table 10. The irrigated agriculture, that roughly occupies 6.8 % of the total cultivated land in Lebanon, has a share of the country´s total water demand of two third. According to the previously assumed 6.8 % of irrigated land and taking the numbers of Table 10 into consideration, irrigated agriculture is under-represented in the NEK Watershed compared to the country´s average.

According to the water balance that is estimated for the various demanding sectors in Lebanon, the domestic and the industrial sector hold equal shares of the remaining water in the year of 2010 (El-Fadel, Zeinati, & Jamali, 2000).

Table 10: Land Use in the five Zones of the Nahr El-Kalb Watershed in Percent with estimated water share

Zone	Urban		Industry		Agriculture		Forests
	Area [%]	Water share [%]	Area [%]	Water share [%]	Area [%]	Water share [%]	Area [%]
1	29	34.02	2	36.58	12	29.4	57
2	43	58.66	2	31.53	4	9.81	51
3	34	63.66	3	26.53	4	9.81	59
4	15	38.97	1	38.97	9	22.06	75
5	6	29.22	1	43.82	10	26.96	83

Source: Author

Certainly, there is much less industrial area in Lebanon than domestic and thus a ratio of domestic to industrial area is assumed at 15 to1.

From these assumptions, the ratio of water distribution amongst the single parties result as presented in Table 10.

Agricultural expansion in the watershed is limited due to the present steep slopes. Furthermore, the probability of the transformation of domestic or industrial land into agricultural is rather small. Thus, no further increase of the agriculture's water share is likely for this watershed.

The ratio of domestic to industrial land reflects the country´s average in most zones of the NEK Watershed. However, an industrial growth rate of 3% is predicted (El-Fadel, Zeinatia, & Jamali, 2001b). This will lead to a redistribution of the water shares among the three competitive sectors within the coming years. Nonetheless, the expansion of industries is expected mainly within the municipality of Jeita, since it is the only area within the first three zones that can offer available space for such a development. The area of Zouk Mosbeh will be totally excluded from further development, since already now no new companies can be licensed due to space constraints. Furthermore, it seems unlikely that a significant number of industries will be established in Zone4 and Zone5, as the distance to the Jounieh Highway is too great.

Although it is attempted in Table 10 to give an indication of the total water consumption by sector, only the consumption of tap water can be reflected. As a bequest of the civil war many farmers and industries still utilize water from private wells. Consequently, the total consumed water of these sectors cannot be stated exactly (El-Fadel, Zeinati, &Jamali, 2000).

Seasonal water demand arises from the two sectors of agriculture and domestic use. As the agricultural sector uses the water for irrigation, consumption finds its peak during the dry season. During winter, precipitation is mostly sufficient for crops and fruit trees.

Further, seasonal demand arises from summer villages in Zone3 and Zone4. In the hot summers of Lebanon families prefer to shift their main domicile to the higher regions of the watershed.

According to these seasonal demands, the percentages that are presented in Table 10 rather refer to the summer situation. During winter the agricultural share should fall significantly in all zones and the domestic share should decrease for Zone3 and Zone4.

2.2.4. Hazards to Water Resources in the NEK Watershed

In general, hazards affecting water quality are to be categorized into three sections: chemicals, biological matter, and suspended solids. For the first two categories, the origin of this material within the NEK Watershed is found in form of septic tanks, urban and agricultural runoff and effluents from industrial activities. Suspended solids are found as abrasion from quarries that are scattered all over the NEK Watershed. This abrasion has negative impacts on aquatic life since it causes turbidity within the water body. Thus, light is prevented from reaching aquatic plants which consequently cannot perform their life sustaining photosynthesis.

Effluents from agriculture that contain high quantities of nutrients like nitrate and phosphorous lead to a blooming of algae. Consequently, conditions for further aquatic life, like fish, worsen, since now by the algae, light is prevented from entering the underlying water.

In addition, chemicals released by agriculture and industries have a further adverse impact on soil conditions and groundwater as well as surface water quality. The excessive discharge of chemicals leads to an increase of bacteria, decaying this matter. During this process the bacteria consume oxygen which is then not available anymore for other aquatic life. The mechanisms and importance of dissolved oxygen, and

biological & chemical oxygen demand are further explained in chapter 3.4. Chemicals or moreover solvents released by industries that are typical for the investigated SUIs are illustrated in chapter 3.2. Furthermore, their impacts on human health and environment are elaborated.

2.3. Localization of Solvent Using Industry (SUI)

According to information gathered at the municipality of Zouk Mosbeh, Jeita, Shaileh, and Ballouneh the great majority of industries are found in the industrial zone of Zouk Mosbeh (ZM). Although this should not be doubted, the single municipalities do not have precise register of existing industries in the area of their responsibility. Moreover, the municipality of Balloumeh stated that no industry is existent at all in the area of their responsibility. Despite that, two Car Paint Shops lying in this municipality had been approached during the conducted research.

However, the majority of companies acknowledged during the carried out research are indeed located within the industrial zone of ZM. A list of accounted companies in the governorate Kessrwan can be found in the Annex II.

Nevertheless, representatives of all five categories of industries under investigation - Printing & Packaging, Smaller Printing Presses, Paint Producers, Car Paint Shops, and Dry Cleaners - are also found sporadically scattered in the three less industrialized municipalities.

Despite the high density of establishments in the industrial zone of ZM, the exact localization of SUI is still challenging, since not all companies are registered at the local industries´ association and thus it happened that major industries of this area were not found on the list that was handed over by the Mayor of ZM. According to the Mayor of ZM, more than 400 companies are located within this industrial zone. However, only

240 companies were listed in the table that was handed over. The entries were partly kept in English and partly in Arabic. No information of the actual location of the company but only Name, type of business and phone number was entered. Unfortunately, no further precise register is existent at the municipality or any other institution.

Outcome

As the major discharge of pollutants appears in the industrial zone of Zouk Mosbeh, the environment of this area is at risk on the highest rate. This zone is located at the outlet of the NEK Watershed. It begins as close as about 500 m direct line to the Mediterranean Sea and reaches into areas where domestic sections are affiliated directly.

Contaminants released to the soil by industries at this location affect groundwater, and possibly enter the distribution system of potable water. Furthermore, channels present in the industrial zone convey wastewaters directly to the Mediterranean Sea and thus might have negative impacts on marine life. Pictures of the scope of pollution discharged to the marine environment can be found in the Annex I.

Furthermore, taking the damages of the potable water network into consideration and with this possible intrusion of materials from its environment, pollutants that have once entered the soil potentially can affect human health.

3. Literature Review

3.1. Legislative and Institutional Frame of Water and Environment in Lebanon

3.1.1. Existing Laws and Regulations

Lebanon started as early as 1925 to regulate water rights and utilization. Based on this, different regulation referring to riparian rights, appropriative rights, a permit system, water codes, regulations regarding cross boundary rivers and a drainage law are in force. Basically, these regulations entitle landowners of abstracting groundwater without restrictions regarding the amount, and foster water rights of the first claimer. If new wells wanted to be drilled authorization must be obtained. However, once the permission is conferred, the owner can utilize the abstracted water for any purpose without any quality monitoring or restriction. Hence, a high rate is sold to households for domestic usages.

The drainage law is in favor of owners of land from higher elevation. They are entitled to discharge their drainage water by natural depression without obstructions of owners of lower lands.

By decree 8735 issued in 1974 the disposal of domestic and industrial wastewater was regulated. It is prohibited by this decree to discharge waste to any natural water source, including marine environment and deep wells (Mallat, 1995). Frequently laws were adjusted and supplemental decrees were released. However, due to constraints elaborated in this chapter, these regulations are effectively not in force. In addition, no law has been approved so far that regulate specifically wastewater discharges of the industrial sector (El-Fadel, Zeinati, El-Jisr, & Jamali, 2001a).

3.1.2. Distribution of Responsibilities

The attempt of describing the distribution of single responsibilities amongst ministries and council for the water sector in Lebanon is challenging. The main responsibility for water related issues is shared amongst the three institutions of Ministry of Water and Electricity, the Autonomous Water Authorities, and the Council for Development and Reconstruction. However, to some extend further shares are hold by several ministries, public authorities and local municipalities. Nevertheless, functional gaps between these institutions and inevitable overlaps limit the efficiency of this huge institutional body.

3.1.3. Institutional Overlapping and Gaps

As Table 11 indicates, task distribution among governmental institutions is weak. Some essential responsibilities are shared with six different parties. This inevitably leads to overlapping, decision conflicts, and inefficient performances. While some tasks face overlapping between too many involved authorities, others are not allowanced at all. Thus, the responsibility in terms of groundwater storage, desalination, water allocation, and enforcement are not assigned to any of the listed institutions. Since Lebanon commonly considered itself, as it is considered by others a water rich country, these tasks might have not been in focus of authorities. However, to mitigate forthcoming water stresses, firm assignation of these tasks must be performed soon.

3.1.4. Constraints of Successful Enforcement

The enforcement of existing regulations fails due to facing a wide variety of challenges. Alike the situation in most countries of the Middle Eastern Regions, governmental laboratories offer only low salaries to staff. Hence, these jobs are attracting only few and among those, a high share of unskilled. Furthermore, staffing is rather based on political influence than on technical qualifications.

In addition, old equipment and the lack of funds for better are forming further constraints towards the effective implementation of water quality control and mitigation.

As stated before, the overlapping of institutional responsibilities frequently leads to a state where no organization takes initiative.

Furthermore the improper financing of the water sector is leading to powerlessness that forbids any improvement of sewage or distribution systems and the construction of facilities like wastewater treatment plants. No cost recovery is achieved, what is further fostered by the failure of collecting fees for water services. In some regions, only 30 to 60 % of the legal connections pay their water bill. In other regions, illegal connections are in number equal to legal connections.

The set-up of water authorities, their responsibilities and limits is inadequate. While some regions in Lebanon have excessive water, others experience shortage. Due to the institutional lack of coordination between water authorities, water stress cannot be eased.

Further, lack of cooperation and data share between administrative bodies poses a further constraint to effective water management.

Table 11: Task Distribution among Institutions

Activity	MWR	Autonomous Water Authority	CDR	MoA	Green Plan	MPH	MoE	NLRA
Surface water								
Use		X						
Storage	X	X			X			X
Recharge								X
Diversion	X	X						X
Quality monitoring		X				X		X
Assessment (Gauging)								X
Groundwater								
Use		X						
Storage								
Recharge	X				X			
Quality monitoring		X				X		
Assessment (Gauging)	X							
Well permits	X	X						
Irrigation network								
Rehabilitation			X	X	X			X
Modernization			X	X	X			X
Reuse								
Drainage water	X			X	X			
Wastewater	X	X	X			X	X	X
Desalination								
Introduction of technology	X			X				
Efficient water utilization								
Domestic	X	X	X					
Industrial	X						X	
Irrigation	X			X	X			
Legislation								
Regulation and codes	X			X				
Standards				X		X	X	
Policy settings	X							
Water allocation								
Project financing	X		X		X			X
Project design	X		X					X
Project implementation	X		X					X
Operation and Maintenance	X				X			X
Pricing (tariffs)	X							
Enforcement								
Water data records	X	X			X			X

Source: (El-Fadel, Zeinatia, & Jamali, Water resources management in Lebanon: institutional capacity and policy options, 2001)

3.2. Description of Typical Solvent at Focused SUI

The illustrated solvents of Table 12, Table 13, and Table 14 reflect the solvents that are mainly used as cleaning agents in the targeted industries. Information assembled in those three tables are taken from material safety data sheets, provided by several chemical laboratories like “Solvay”, “Shell Chemicals”, and “lab-scan”.

The cleaning agent that is mostly used in the sector of Car Paint Shops is known under the umbrella term of “Thinner”. Hence, solvents that are usually used as such are mentioned in the tables.

Paint Producers partly share solvents of the umbrella of “Thinner”. Further used have been supplemented. Among others, these are Xylene and Toluene.

The solvents that are used for cleaning purposes in the sector of Printing & Packaging are mostly Isopropanol and Ethyl Acetate.

Most Dry Cleaners utilize Perchlorethylene for dissolving grease and oil from cloths.

Some of the mentioned solvents are highly toxic to aquatic life. Others are of lower hazardous category and readily biodegradable. Although, this might seem to be positive at first sight, severe depletion of DO related to the rapid decaying of this material might affect water bodies negatively.

Since the supply system of potable water is highly damaged within the watershed and supply is not continues, spilled solvents could enter directly the water network and thus could reach within shortest time consumers. In this context, the assembled tables reveal acute and chronic health impacts to humans if exposed to the listed solvents. Due to the relatively high dilution of contaminants in water, the probability of acute impacts might be low. However, if occurring, symptoms of acute affection include: vomiting, irritation of skin, dizziness, effects on central nerve system, and allergies could result. If exposed to the concerned solvents over a longer period of time, chronic health impacts might

result. These can lead to damages of kidneys and liver, cause blood diseases, including anemia and leukemia, and act further carcinogen. In addition, released solvents can affect the central nerve system, reduce fertility and pose a risk of harming unborn life. The consumption of alcohol in combination with being exposed to Perchlorethylene may enhance toxicity further.

As in all focused industries but Dry Cleaners pigments are involved, eventual toxicity of those must not be neglected. In the past heavy metals have been utilized as strong and low cost pigments. Although, Lebanese standards condemn their application, illegally imported material finds its way into Lebanese inks and paints. Hence, the appearance of heavy metals in used solvents that contain ink residues cannot be excluded. Typical heavy metals used as pigments are Antimony, Cadmium, and Chromium (lenntech, 2009).

The Lebanese standard for potable water sets a limit value of halogenic organic compounds, in this case Perchlorethylene, of 0.06 mg/l (LIBNOR, 2009). This strict limit, that is more than 80 times lower than the actual eco-toxicity, reflects the hazardous potential of this solvent.

Unfortunately, from the current abstract of the Lebanese standards, no further parameters reflect intrusion of the illustrated solvents.

Table 12: Expected Solvents of Focused Industries (1)

	Mineral Turpentine	Naphtha	Toluene
Hazards Identification	• HAZARDOUS SUBSTANCE. DANGEROUS GOODS. • Classified as hazardous according to the criteria of NOHSC, and as Dangerous Goods according to the Australian Dangerous Goods Code.	• Extremely flammable	• Flammable liquid and vapor
Potential Acute Health Effects	May cause moderate irritation to skin. Harmful: may cause lung damage if swallowed.	• Irritating to eyes and respiratory system. • Affects central nervous system. • Harmful or fatal if swallowed. • Aspiration Hazard.	• Harmful fatal if swallowed. • Harmful if inhaled or absorbed through skin. • Vapor harmful • Causes irritation to skin, eyes and respiratory tract
Potential Chronic Health Effects	Repeated exposure may cause skin dryness or cracking Possibility of organ or organ system Limited evidence of carcinogenic effect	Long-term exposure may cause effects to specific organs, such as to the liver, kidneys, blood, nervous system, and skin. Contains benzene, which can cause blood disease, including anemia and leukemia	• May affect liver, kidney, blood system, or central nervous system.
Hazardous Decomposition Products	Carbon monoxide, carbon dioxide and other organic compounds evolve when undergoing combustion or thermal/oxidative degradation	Carbon monoxide, carbon dioxide and non-combusted hydrocarbons (smoke)	Carbon dioxide and carbon monoxide may form when heated to decomposition
Ecological Information	Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment	Should not be released into the environment. Avoid subsoil penetration. If the product contaminates rivers and lakes or drains, inform respective authorities	Do not release to environment. Inform responsible authorities if material is spilled to soil or water bodies
Mobility	Floats on water.	N.A. since mixture of various solvents	Miscible with Water
Degradability	Readily biodegradable Oxidizes rapidly by photo-chemical reactions in air	N.A. since mixture of various solvents	
Ecotoxic effects	Fish : Expected to be toxic; Aquatic Invertebrates : Expected to be toxic Algae: Expected to be toxic ; Microorganisms: Expected to be toxic	Toxicity to fish: LC50/96h (Pimephales promelas): 2.5 mg/l EC50/48h (Water flea): 2.1 mg/l	Expected to be toxic to aquatic life. The LC50/96-hour (fish): between 10 and 100 mg/l

Table 13: Expected Solvents of Focused Industries (2)

	White Spirit	Xylene	Perchlorethylene	Isopropanol
Hazards Identification	• Flammable. • Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.	• Flammable.	• Harmful • Dangerous for the environment • Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment..	Hazardous by definition of Hazard Communication Standard
Potential Acute Health Effects	• May cause lung damage if swallowed. • Vapours may cause drowsiness and dizziness.	• Harmful by inhalation and in contact with skin. • Irritating to skin.	• The product causes irritation of eyes, skin and mucous membranes	Hazardous in case of eye contact (irritant), of ingestion, of inhalation. Slightly hazardous in case of skin contact (irritant, sensitizer, permeator)
Potential Chronic Health Effects	• Repeated exposure may cause skin dryness or cracking.		• Limited evidence of a carcinogenic effect • Liver and kidney injuries may occur • Risk of cardiac and nervous disorders • Use of alcoholic beverages may enhance toxic effects	The substance may be toxic to kidneys, liver, skin, central nervous system (CNS). Repeated or prolonged exposure to the substance can produce target organs damage. May cause adverse reproductive effects
Hazardous Decomposition Products	Toxic: Carbon monoxide, Carbon dioxide	In combustion emits toxic fumes	hydrochloric acid, Carbon monoxide, Phosgene	products are carbon oxides
Ecological Information	Do not discharge into drains or rivers. Contain the spillage using sufficient appropriate absorbent material.	Do not discharge into drains or rivers.	Dispose of rinse water in accordance with local and national regulations	Do not discharge into drains or rivers
Mobility	Floats on water	Not miscible with water, floats on water	Partly miscible with water, Heavier than water	Soluble easily with water
Degradability	Inherently biodegradable	Biodegradable	Inherently biodegradable	Biodegradable
Ecotoxic effects	Fish LC 50/96h: 10 mg/l	Negligible ecotoxicity.	Fishes, Salmo gairdneri, LC50, 96 h, 5 mg/l	Ecotoxicity in water (LC50): 100000 mg/l 96 hours [Fathead Minnow].

Table 14: Expected Solvents of Focused Industries (3)

	Aceton	Dimethylformamide	Methyl Ethyl Ketone
Hazards Identification	• Highly flammable. Irritating to eyes.	• Danger of cumulative effects, teratogenic. • May cause long-term adverse effects in the environment.	• Highly flammable.
Potential Acute Health Effects	• Vapours may cause drowsiness and dizziness	• Irritating to eyes, respiratory system and skin. • Harmful by inhalation and in contact with skin. • The substance can be readily absorbed through intact skin	• Vapours may cause drowsiness and dizziness • Irritating to eyes.
Potential Chronic Health Effects	• Repeated exposure may cause skin dryness or cracking. • Central nervous system. Eyes. Respiratory system, lungs. Skin • Skin disorders and allergies	• Possible risk of harm to the unborn child • injuries to gastrointestinal tract, liver, kidneys and central nervous system • Danger of serious damage to health by prolonged exposure to solvent	• Repeated exposure may cause skin dryness or cracking.
Hazardous Decomposition Products	Thermal decomposition or burning may release oxides of carbon and other hazardous gases or vapours.	Carbon monoxide / Dimethylamine	May form peroxides
Ecological Information	Prevent contamination of soil, drains or surface water, use appropriate containment method to avoid environmental contamination	Prevent liquid entering sewers. If substance has entered a water course or sewer or contaminated soil or vegetation, advise police.	Do not allow to enter sewerage system. Take up with non-combustible liquid-absorbent material and place in approved containers for disposal
Mobility	Soluble in water	Miscible with water.	Miscible with water
Degradability	Poses a significant risk of oxygen depletion in aquatic systems. Environmental half-life expected to be 1-<10 days.	Readily biodegradable, risk of significant oxygen depletion in aquatic system	Readily degradable. Risk of formation of explosive vapours above water surface
Ecotoxic effects	Fish: LC50/96h: 8300 mg/l	Fish LC50/96h:7.1-10.6 gl-1. EC50/48h/daphnia = 14.5 – 36.2 g-1. EC50/72h/algae = > 500 mg/l	Fish LC50/96h: 3220 mg/l (Pimephales promelas). Daphnia Magna EC50/48h: >5091 mg/l.

3.3. Expected Industrial Growth in the Governorate of Kessrwan

The projection of industrial growth rates must refer to estimations that lack for a greater extant basic data. As mentioned in 2.2.3, the fundamental question of the number of inhabitants in Lebanon is not cleared. Estimations for 2010 reach from 3.5 to 5.5 Million inhabitants. Industrial growth is strongly related to this basic information (El-Fadel, Zeinatia, & Jamali, 2001b).

Statements regarding the industrial growth rate throughout Lebanon vary drastically between the different sources. The country is profiting from relative political stability since a few years. This is reflected in a great industrial development. Despite the uncertainties, a mean growth rate of 5 % for the time period of 2001 to 2020 is assumed for total Lebanon. Interestingly enough, the highest growth rate could be witnessed over the last years and is projected for the coming years in industrial activities that produce the most hazardous waste (El-Fadel, Zeinati, El-Jisr, & Jamali, 2001a; El-Fadel, Zeinatia, & Jamali, 2001b). In case of not applying any mitigation measures, a proportional high increase of pollutants released to the environment resulting from the industrial sector is most likely.

Figure 6illustrates the expected growth rate of hazardous industrial liquid waste until the year of 2025. Although the total share might occur not to be great, the waste categories of paint/resins and organic solvents will increase significantly, yet. If no mitigation measure will be introduced, this hazardous material will inevitably lead to water pollution, since no safe disposal facility is in force, nor planned. Solvent and paint recycling could help to prevent the increasing waste generation of having an increasingly negative impact on the environment.

However, according to the information gathered at the municipality of Zouk Mosbeh further significant industrial growth is not expected in this district within the next years. The restriction of further expansion is related to the simple fact that the industry in this area is already seizing all available space. Nevertheless, the expansion of the local industry is not to hold up and thus neighboring municipalities like Jeita and Shaile will probably experience significant industrialization within a short time period. However, due to the space constraints industrial growth in this region will not correlate with the country´s total. Thus, it would be not correct to project the earlier stated 5 % on the quantity of future available used solvents in the Kessrwan region.

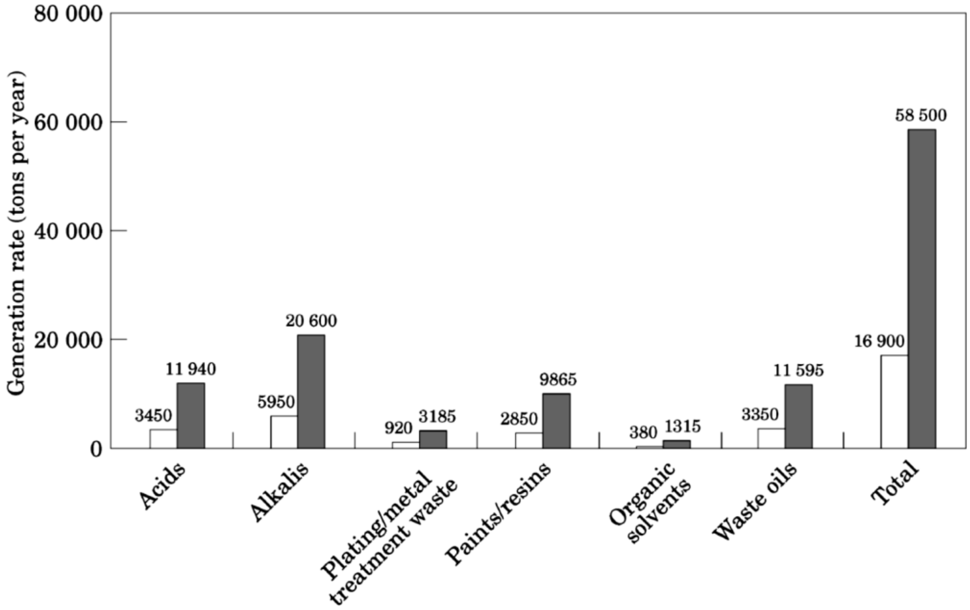


Figure 6: Estimated hazardous-waste generation based on industry types and employment data. 1995 (white); 2020 (grey)
Source: (El-Fadel, Zeinati, El-Jisr, & Jamali, 2001a)

Outcome

In case of intense industrial development without mitigation in the municipalities of Jeita and Shaile not only environmental degradation could occur, but human health could be directly at risk. The named municipalities are part of the water catchment area that feeds the Jeita Spring and the Qachqouch Spring. These springs serve as main

sources of potable water for greater Beirut. Fresh water abstracted from these springs undergoes only minor treatment and is than directly conveyed to its recipients. Hence, any contaminant reaching this water body is a potential threat to human health.

Furthermore, the distribution network for potable water in the area of the mentioned municipalities is damaged and leaking pipes are normality. Many spots could be viewed where the leakage rate is actually that high that water finds its way through the asphalt of the streets. As mentioned in the previous chapter 2.2.2, the network for potable water is not always pressurized. Consequently, with dropping pressure within the pipe, particles from the pipe´s environment can be sucked in. In case these particles are hazardous contaminants, consumers are not protected towards this material by any kind of treatment but are directly exposed to the health threatening pollutants. The hazardous potential of chemicals used at the local industries are illustrated in Table 12, Table 13, and Table 14 in chapter 3.2.

3.4. Water Quality Indicators

Dissolved Oxygen

As fish and other aquatic animals highly depend on oxygen that is dissolved in a water body, the measurement of the latter is essential for stating a certain water quality. The amount of dissolved oxygen (DO) in a water body depends on several factors like the water temperature, the amount of oxygen that is taken out by respiring and decaying organisms, the ratio of oxygen that is added to the water by the photosynthesis mechanism of aquatic plants, and turbulences within the stream that are followed by aeration of the water.

The temperature of a water body influences the solubility of oxygen. The warmer the water is, the lower the ability of keeping the oxygen. Thus, seasonal variations of

measured DO are not necessarily related to an improvement or worsening of external conditions acting on the water body, but related to its ability of binding the oxygen. Consequently, during winter the amount of DO is naturally higher than during summer. Each water temperature offers a different saturation value of oxygen. A water body is considered as healthy if having an oxygen saturation rate of 90 to 100%

The amount of dissolved oxygen is measured in parts per million (ppm) or more commonly in milligrams per liter (mg/l).

Generally, DO levels of less than 3 mg/l are stressful to most aquatic organisms. However, most fish die at 1-2 mg/l.

Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)

The BOD is an indicator for the oxygen that is consumed by bacteria while decomposing organic matter und aerobic conditions. This organic matter can originate from naturally occurring sludge, waste from wastewater treatment plants (WWTP), from failing septic tanks, and from agricultural and urban runoff. Usually, the oxygen that is taken out by the bacteria for decaying the organic material of the sample is measured over a period of five days (BOD_5).

Despite the BOD, the COD does not differentiate between biologically available and inert organic matter. Moreover, it measures the oxygen that is needed to oxidize or decay the total organic material of a sample into carbon dioxide and water. The measurement of the COD can be performed within approximately 4 hours. Generally it is to state that COD values are always roughly double of BOD values, even in high quality potable water. If the COD value reaches a triple of the BOD, serious chemical contamination can be assumed.

When BOD and COD are high, the ratio of DO in the sampled water is depleting proportionally. Moderately polluted rivers and lakes possess a BOD_5 of 2 to 8 mg/l (Dr. Ch. Rieker, pers. comm.).

As Lebanon faces serious problems of soil erosion, soil that is flushed into the water bodies contributes significantly to an increase of nourishments for bacteria.

WWTPs are not present in the watershed and thus their effluents do not contribute at the moment. However, it is intended to build a WWTP within the coming years. Currently, finding a suitable location seems to be the biggest challenge. However, even if no accidental spillage happens, the WWTP might still add a significant pollution load to the river. This would result from the frequently interrupted supply of electricity, which would lead to the discharge of partly untreated sewage.

The main source of organic material in the NEK Watershed might be the numerous failing septic tanks. As most of the areas are not connected to a sewage system, septic tanks are common practice. Furthermore, common practice is not to empty the septic tanks in a legal way but instead to discharge the content to the soil. During the winter season when heavy rain is present in the watershed, many of the septic tanks do additionally overflow. Then, the effluent reaches directly with the runoff the nearest water body.

The second highest source of pollution might be the agricultural and urban runoff. As described in chapter 3.5, agriculture uses an excessive amount of fertilizers, pesticides and herbicides. These materials enter the water cycle after have been washed out by heavy precipitation.

COD/BOD Measurements in the NEK Watershed

As explained above, the measurement of the BOD and COD is essential for making accurate statements regarding the actual water quality.

Many of the solvents that are used and disposed in the NEK Watershed are readily biodegradable. Consequently, they are rapidly decayed by microorganisms which consume a considerable amount of oxygen during that process. As the microorganisms find by this rich offer of nourishments good conditions, they multiply which is followed by a proportional increase of oxygen consumption. Hence, a solvent that at first sight seems to be environmental friendly and not harming if entering a water body, can have adverse effects on aquatic life. Its characteristic of being readily biodegradable could lead to a rapid increase of the BOD and COD within a water body and thus to a severe depletion of DO.

For the NEK Watershed no measurements of COD or BOD are conducted on regular basis. The only available measure of BOD_5 from the Nahr El-Kalb dates back to 1999 and revealed a level of 26.3 mg/l (MoE, 2001). Due to shortages in terms of laboratories, staff, institutional frames, and money it is unlikely that measurements will be conducted any soon by local institutions on regular basis. Moreover this task might be fulfilled by foreign governmental and non-governmental organizations that are active in this region.

However, if these measurements would be taken, the spots of water sampling must be chosen carefully. One company producing detergents is located within the watershed. It was witnessed on nearly daily basis that this company discharges its wastewater that was loaded with huge quantities of detergents directly to a nearby channel. As these cleaning agencies are designed to deactivate bacteriological activities they could falsify BOD and COD measurements. As the microorganisms are deactivated they do not demand oxygen for the process of decaying material. As a result, although pollution of

the water body might be high, the BOD might be low and thus spuriously indicate a good water quality. Then, only the COD would pose an adequate measure.

pH

The indicator of pH expresses the balance between positive hydrogen ions (H^+) and negative hydroxide ions (OH^-). By measuring this value it can be determined whether a water body has acidic or alkaline tendencies. A value of 7 states a neutral status. Values lower 7 indicate acidic conditions, values greater 7 reveal an alkaline environment. The total scale of pH values ranges from 0, extremely acidic, to 14, extremely alkaline. Typical values for healthy water bodies lie in a range of a pH of 6.5 to 8.5 (LIBNOR, 2009)

The pH value of a certain water body is influenced, among others, by the concentration of Carbon Dioxide (CO_2) solved in it. Source of this can be the surrounding atmosphere, runoff from urban and forest areas, side product of bacterial activities, and the respiration of aquatic life.

Measuring the pH is from special importance for interpreting the current water quality, since the balance between hydrogen and hydroxide ions influences the impact of pollutants added to the aquatic system. Accordingly, a low pH enhances a high solubility of (heavy) metals from sediments and rocks. Furthermore, it raises the solubility and thus the bioavailability of substances trapped in runoff. Consequently, the toxicity of contaminants (like lead, chromium, ammonia, mercury or other elements) is increased and thus possible negative impacts on aquatic life and human health are amplified.

Nitrogen (N_2)

This element is found in nature abundantly. More than 80 % of the air consists of it and it is an essential nutrient for many species relying on photosynthesis. However, in water it occurs naturally in the form of Nitrate (NO_3^-), and Nitrite, (NO_2^-) and its availability is identified as growth limiting factor. The presence of Nitrate is the most common form tested. Nevertheless, the presence of Nitrogen in form of Ammonia (NH_3) is highly toxic to aquatic life and cause fish death from a level of 0.2 mg/l (Oram, 2006).

The effluents of wastewater treatment plants and septic tanks are one major source of Nitrates. Nevertheless, runoff from agricultural areas contributes with a further huge share to the total Nitrate budged. The application of synthetic fertilizers containing this element and animal waste in form of manure lead to this contribution. Furthermore, fossil fuels are to mention as a source. Naturally they contain about 1% Nitrate what finds its way into water bodies via rain after their combustion (Oram, 2006).

Industrial processes request the application of Nitrate as inhibitor for corrosion, and Ammonia in cleaning supplies and as water softener.

Excessive concentrations of Nitrate and/or Nitrate can be adverse for human health and wildlife as it prevents red blood cells from taking up oxygen if entering the body. This phenomenon is known as the "blue baby" syndrome, since especially young children are sensitive towards this kind of intoxication.

Phosphate

Phosphate is a further key element for growth of animals and plants.

Sources for it are domestic and industrial sewage containing body waste, food residues, manure, and detergents. As it finds its application in nearly every fertilizer, agricultural runoff once more has a significant share to the total Phosphate budget of a water body.

The excessive concentration of Phosphate, as the high concentration of Nitrate, leads to the eutrophication where the wild growth of algae and aquatic plants can choke up waterways, and use up large amounts of oxygen. Hence, it can result in a significant drop of DO and thus in death of aquatic life.

Temperature

Different aquatic species tolerate only slight variations of temperature during certain phases of their life cycle.

A wide range of factors influence the water´s temperature. Some of them are factors manipulated directly by human´s action. As consequence of the root out of forest, soil erosion became a major problem in many regions. The washed out soil is flushed into rivers where it causes significant turbidity. The higher the turbidity and thus darker the water, the more heat from the sun can be absorbed by the water. This leads to an increase of temperature. Furthermore, the abstraction of water from rivers or groundwater that is feeding rivers leads to a depletion of water level and to a reduction of flow rate. The lower the water depths and flow rate, the more the water can be heated up by sun rays. Many industrial activities use river water for cooling their machinery. The discharge of warmed up water poses thermal pollution to the water body. As finale influencing factor, but not only on minor level related to human activity is to mention seasonal variations. By nature, temperature of most water bodies changes throughout the year according to the surrounding temperature.

Increased water temperature results in a lower capability of binding oxygen which is followed by a decreased water quality. Furthermore, with increased temperature the reactivity of certain chemicals raises and with this their possible negative impacts on health and environment, so to say their toxicity. A certain level of temperature

determines the rate of metabolic and reproductive activities of aquatic life. In line is the activity of bacteria relying on a specific water temperature.

3.5. Contamination of Water Bodies Recorded so Far

In the matter of the contamination of water bodies so far, the NEK Watershed is lacking sufficient data.

The document “The Environmental Impacts of Humans on Groundwater in Lebanon” (Khair, Aker, Haddad, Jurdi, & Hachach, 1993)is referring to the contamination of groundwater due to salt intrusion in the coastal zones of Lebanon and cesspools. The ratio of cesspools to sewer lines in the NEK Watershed is even much higher than the one illustrated in Table 15. However, Table 16 gives a good overview of the consequences of this method of sewage disposal.

Method	Quantity %
Cesspools	63.8
Sewer Lines	36.2

Table 15: Methods of sewage disposal in Lebanon
Source: (Khair, Aker, Haddad, Jurdi, & Hachach, 1993)

Source	Wet		Dry	
	Compliance (%)	Noncompliance (%)	Compliance (%)	Noncompliance (%)
Springs	33.0	67.0	27.8	72.2
Wells	36.7	63.3	49.9	50.1
Reservoirs	49.3	50.7	27.3	72.7
Network	32.6	67.4	40.5	59.5

Table 16: Bacteriological contamination of potable water resources in Lebanon (Mean values for 1420 samples, wet and dry season)
Source: (Khair, Aker, Haddad, Jurdi, & Hachach, 1993)

Although the current research evaluates on the water pollution originating from industrial activities, the information about the whereabouts of domestic wastewater serves as an indicator of what is happening to industrial wastewater. As Table 15 shows,

63.8% of all households discharge their wastewater into cesspools (Khair, Aker, Haddad, Jurdi, & Hachach, 1993). This method of disposing wastewater is leading to the sampling results that are illustrated in Table 16. Up to 72.2% of the collected samples do not comply with the standards established by the Lebanese organization LIBNOR in terms of limitation to bacteriological contamination. Despite the fact that this data is relatively old, due to financial and personnel deficits, this ration did not improve to the present day.

Besides cesspools, septic tanks are applied in domestic areas for wastewater disposal in the NEK Watershed. The difference between the two systems is that cesspools are bottomless. Consequently, all influences can infiltrate into the soil. Contrarily, septic tanks are meant to be closed systems that, once they are full, have to be emptied by pumping the wastewater into a transporter that delivers the sewage to a place of safe disposal or treatment. However, this closed system is interrupted since most owners of the septic tanks just open a valve and discharge their wastewater to the environment, as soon as the rainy season in Lebanon has started for avoiding the fee they should pay for the emptying of their septic tank. Furthermore, as soon as the rainy season starts, many septic tanks overflow and thus as significant amount of sewage enters with other urban runoff the watershed´s water cycle.

“The Study of Nahr El-Kalb Watershed” (AVSI; NDU, 2009)identifies in the area of Kessrwan 7,062 septic tanks that are located in 12 villages. In the region of Al Metn 3,606 septic tanks in 21 villages could be identified. Since the two governorates host much more villages than these in total 33, the number of the spotted 10,868 septic tanks can give only a rough but yet frightening hint of the dimension of the pollution load the investigated watershed receives due to domestic wastewater intrusion.

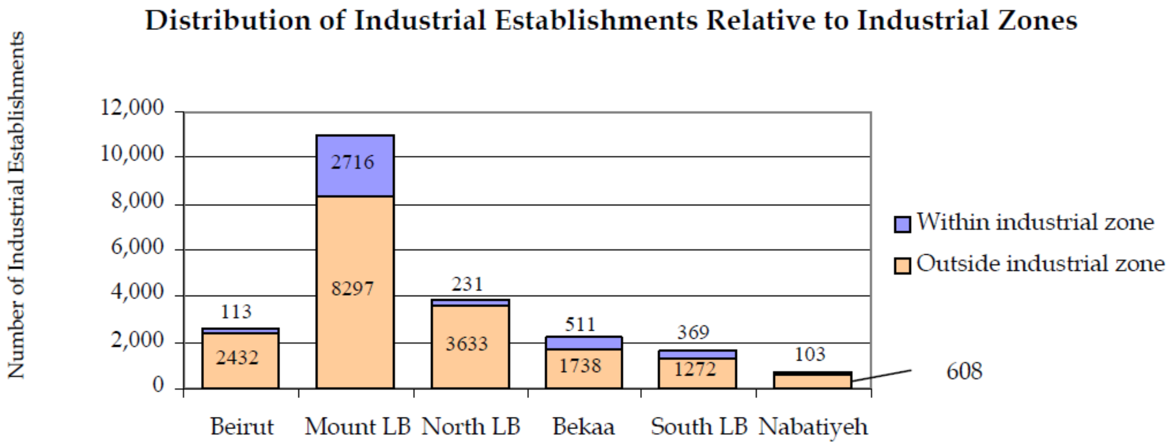


Figure 7: Distribution of Industrial Establishments Relative to Industrial Zone

Source: (AVSI; NDU, 2009)

Since the industrial areas suffer from inadequate planning and deficient physical infrastructure, local industry adopted the domestic way of handling wastewater. Hence, the wastewater is discharged into cesspools, open canals and piping systems that end either in the Mediterranean Sea or other adjacent water bodies. As Figure 7 shows, most of the industry found in Lebanon is located outside declared industrial zones. For the region of Mount Lebanon where the described watershed is located in, only a quarter of industries lay within such an announced area. Although this is nearly the highest share amongst Lebanon it results in 8,297 companies that are scattered in domestic areas.

Furthermore "The Study of the Nahr El-Kalb Watershed" investigated the parameters of Fecal Coliform Bacteria, pH and temperature. These measures do reflect the contamination resulting from domestic wastewater. Nonetheless, they do not reflect any of the other activities within the watershed. Additionally, even if all measurements would have been taken, pollution induced by industrial activities with special respect to applied solvents was not represented adequately.

Industrial-waste management in developing countries: The case of Lebanon

The paper prepared by El-Fadel, Zeinati, El-Jisr, and Jamali (2001a) refers to the different kinds of non-hazardous and hazardous waste solid/liquid originating from domestic as well as from industrial activities. They elaborate on current and projected industrial waste loads in Lebanon and possible management options. Further, waste quantities of paints and resins and organic solvents estimated in the 1995 and projected for the year 2020 are stated in this paper. As paints and resins reach a load of 2,850 tons/year in 1995, it is estimate that they will reach 9,865 tons/year in 2020. Organic solvents are numbered for 1995 at 380 tons/year. This is meant to increase to 1,315 tons/year by 2020. Nevertheless, the paper does not offer a specification of the used solvents and their hazardous degree. Furthermore, recycling is not seen as a real option since high investment costs are associated with this technique.

The industrial zone of Zouk Mosbeh in the NEK Watershed is characterized in this paper as a Class-B Zone. This means, the industrial activities can cause a serious threat to environment and disturbance to their surroundings.

In the Context of the Study

The conducted research cannot fill the gap of missing sampling and testing data. Yet, it shall help to identify some of the actual pollutants that are released by the industries of the NEK Watershed in the area of Kessrwan. Hence, future water quality testing can refer to these contaminants and thus trace back its origin. Consequently, principles like “polluter pays” become finally applicable. This shall contribute in developing water sampling to a tool of action and not only of documentation.

3.6. Costs of Environmental Degradation in Lebanon

The report of “Costs of Environmental Degradation: The Case of Lebanon and Tunisia” (Sarraf, Larsen, & Owaygen, 2004)elaborates on first order estimates on the cost of

environmental degradation in Lebanon, as well as the cost of remediation of environmental degradation for selected actions. However, recommendations of the remediation fall short and cannot support the present case of the research on the NEK Watershed.

In the viewed study an attempt to capture what is expected to be the most significant costs of degradation has been made. Nevertheless, data limitations have been a constraint, which implies that estimates in some environmental areas are not included. Hence, the total estimate of environmental degradation, as presented in this study, is likely to underestimate the true costs of degradation.

The cost of environmental degradation can be understood as a measure of the lost welfare of a nation due to environmental degradation. This includes aspects like the loss of healthy life and well-being of the population expressed by premature death, development of illness, the absence of a clean environment, and a resulting general feeling of discomfort. Table 17 illustrates the mean estimates for Lebanon of annual damage costs originating from lowered water quality and thereby reduced health and additional expenders for bottled water. Only effects of potable water related degradation leads costs having a share of 1.07 % of GDP. In addition, economic losses are recorded by factors like reduced soil productivity, and reduced value of other natural resources, what among others might result in lower international tourism. In this context, loss of environmental opportunities in terms of reduced recreational value for lakes, rivers, beaches, and forests are to state.

Table 17: Annual Damage Costs Related to Water/Health, Mean Estimates 2000

Water	**Percent of GDP**
Health impacts (DALYS)	0.25
Treatment costs of illness	0.31
Additional expenditures (bottled water)	0.51
Total	**1.07**

Source: (Sarraf, Larsen, & Owaygen, 2004)

Total Costs of Degradation

Total costs of environmental degradation in Lebanon in 2000 is estimated at 2.8 - 4.0 percent of GDP, with a mean estimate of565 $ million, what represents 3.4 % of GDP. The damage cost to the global environment is estimated at 0.5 % of GDP.

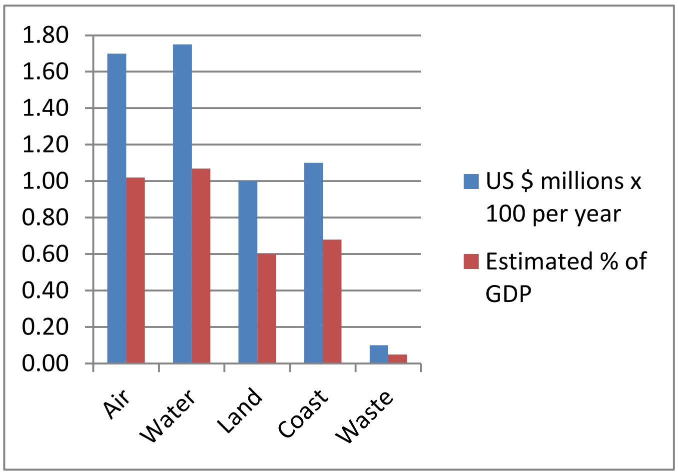


Figure8: Costs of Environmental Degradation in 2000 Source: **(Sarraf, Larsen, & Owaygen, 2004)**

Hence, it is clearly to see that Lebanon suffers from extreme environmental degradation compared to world average. Mean estimates of degradation costs are presented in and Figure8, (exclusive of the global environment) for each environmental category. The categories of air and water have by far the biggest share of total degradation with about 1.7 % and 1.75%. As water resources are getting increasingly scarce in Lebanon, water degradation must be of special concern.

3.7. Proposed Pollution Mitigation and Prevention Measures

A wide range of literature refers to the mitigation and prevention of pollution resulting from residential areas and agricultural activities. However, only little has been researched on the options for the prevention of industrial pollution. Nevertheless, information found shall be illustrated by the following.

3.7.1. Mitigation Measures

Respecting the weak infrastructure of Lebanon in terms of sewage systems, most recommendation regarding the mitigation of environmental pollution refer to the

installation of proper sewage networks, generally wastewater treatment plants, special treatment plants for industrial zones or on-site wastewater treatment in de-centralized facilities. Further, the recycling of wastewater to make it suitable for re-use is recommended (AVSI; NDU, 2009; Khair, et al., 1993; El-Fadel, et al., 2001).

Additionally, the implementation of identified protection zones around wells, the change of land use, and water monitoring are postulated. This should be accompanied by the enforcement of the existing legal framework (El-Fadel, Zeinatia, & Jamali, 2001).

3.7.2. Prevention Measures

In terms of pollution prevention first attempts of implementing the principles of Resource Efficiency and Cleaner Production (RECP) have been undertaken. The definition of this concept was formulated by the UNEP in 1990 as following: "*Cleaner Production is the continuous application of an integrated, preventive strategy to processes, products and services to increase efficiency and reduce risks to humans and the environment"*. Accordingly, main aims are stated as to increase the production efficiency in order to optimize the productivity of natural resources (materials, evnergy, water) at all stages of the production cycle, enhance environmental management through the minimization of harming impacts on nature and environment originating from industrial production, and stated in human development where the minimization of risks to people and communities is claimed.

In this context, the Lebanese Cleaner Production Center (LCPC) (http://www.lebanese-cpc.net/) was established in 2002. Addressing small and middle size enterprises of the sectors of Dairy, Agro-Food Canning, Paper & Cardboards, and Plastic, the organization influenced by the end of 2007 more than 140 institutions and could achieve

yearly monetary savings of total 793,206 $. These savings are resulting from the reduced application of material and energy, waste generation and hence waste management costs, as well as the improvement of quality and increased lifespan of products, working conditions for workers, and the public image of the company.

These improvements are achieved by the transfer of environmentally sound technologies (EST) from developed to developing countries. However, local conditions must be respected during this transfer and if necessary technologies adjusted (UNEP, 2002).

Following the concept of RECP, the Environmental Fund for Lebanon (EFL) is seeking in cooperation with the Lebanese Council of Development and Reconstruction (CDR) and the supported funding of the German government via Gemeinschaft für technische Zusammenarbeit (GTZ) the implementation of projects (www.efl.cdr.gov.lb)

Private industries can apply for funding of actions enhancing cleaner production and the increasing efficiency of use of materials, resources, and energy. Among those, water is a specially highlighted resource. This addresses companies throughout entire Lebanon but especially the industrial zone of the municipality of Zouk Mosbeh. However, applying projects should be related to the protection of water resources and the prevention of pollution to those.

By now, no project has been implemented in the field of solvent recovery. However, the necessity of intervention in the increased negative environmental impacts of SUI was acknowledged by the EFL and thus a first call for application of this sector was launched.

3.8. Policy Instruments for Environmental Management

Various tools are available for enforcing environmental management. To foster environmental production, instruments as illustrated in Table 18 are utilized. It is intended to regulate actions by mechanisms of price types, rights, regulations and information. Referring to the criteria of effectiveness, fairness in terms of distribution of costs and benefits, compatibility to incentives, political feasibility, and the costs and information needed for implementing an instrument the adequate tool is chosen for the certain situation (Sterner, 2006).

Table 18: Categories of Policy Instruments for Environmental Management

Policy Instruments			
Price Type	**Rights**	**Regulations**	**Info/Legal**
Taxes	Property Rights	Technological Standard	Public Participation
Subsidy (Reduction)	Tradable Permits	Performance Standard	Information Disclosure
Charge, Fee/Tariff	Tradable Quotas	Ban	Voluntary Agreement
Deposit-refund	Certificates	Permit	Liability
Refunded Charge	CPR	Zoning	

Source: (Sterner, 2006)

However, the interaction of these tools is the basis for sound environmental management and the constant improvement of their efficiency is mandatory for sustainable development (Reeson, 2008).

The following paragraphs elaborate on the most common instruments of the mentioned categories and the feasibility of application in Lebanon.

Laws and regulations:

Laws and regulations build the basis for any environmental management strategy. Furthermore, they should reflect the governmental policy and incorporate local conditions (Bell, 2003). However, the effective implementation of the instrument of laws and regulations needs a strong legal framework. To ensure compliance to them, a large apparatus of monitoring staff and cross-checking mechanisms are required. Furthermore, the conscientiousness of the hired staff is precondition for a successful implementation.

Currently this large apparatus is not in force in Lebanon. The responsible institutions are chronically understaffed and partly corrupted. Additionally, the Ministry of Environment is lacking power and not in the position of enforcing considerable changes. This makes all established laws, regulations and decrees ineffective.

Environmental Education:

The establishment of awareness among a certain group of people through environmental education is a long term process, which requires huge capacities in terms of money, staff, public relations, and time. None of this is currently available in the governmental budged in Lebanon (El-Fadel, Zeinati, & Jamali, 2000b). This task is performed at the present by external organizations (El-Fadel, Zeinati, & Jamali, 2001b). However if implemented, this tool reaches only specific groups of people and might not affect the perception towards environmental issues from those considered of being main polluters. Nevertheless, environmental education should be included in any holistic approach of environmental management, since it conveys the necessity and sustainable and voluntary compliance of environmental regulations.

Social Pressure:

The precondition for the raise of social pressure is the awareness about certain issues by a society. Exactly this awareness is lacking tremendously in Lebanon. As stated in the previous paragraph, building up this awareness is a long term process. Thus, social pressure cannot be considered as an effective tool for the moment.

Incentives:

In the repertoire of instruments for enforcing environmental friendly production or behavior, incentives might have the shortest warm-up time. Individuals start changing their behavior, since they acknowledge direct benefit for themselves by this change. Hence, contrarily to the above mentioned instruments, individuals do not need to be convinced to bear an extra burden for the sake of achievements for a superordinate society (Reeson, 2008).

3.8.1. Frame for Cleaner Production and Technology Transfer

Worldwide, progressing industrialization increases environmental stress and threatens living conditions of many, predominantly the poorest. The increase of Greenhouse gases, that is meant to accelerate climate change, is of great concern and has been acknowledged by many organizations. Among those is the section of United Nations Framework Convention on Climate Change (UNFCCC). It has been explicitly established for finding solutions of preventing further human influence on climate change. The strategy to transfer technologies from developed to developing countries is seen as key to that. Thus the sustainable use of resources and development of industries should be supported. This is expressed in the concept of “cleaner production” (CP), where instead of managing outputs of emissions and waste, producers are guided to improve management of raw materials and other inputs, such as energy and water, from

the moment a product or process is conceived (LCPC, 2002). In this context, the United Nations Industrial Development Organization (UNIDO) has established cleaner production centers in more than 30 developing countries since 1992. In 2002, the Lebanese cleaner production center LCPC was established.

The concept concentrates on improving economy wide productivity in a sustainable manner. Furthermore, it attempts to enable developing countries and countries with economies in transition to expand their share in world trade. This is achieved by the diffusion of quality and productivity enhanced by ESTs, which allows the fulfillment of requirements of international markets (UNEP, 2002).

The holistic and sectoral CP approach furthermore refers to health, safety, and labor aspects.

However, CP poses strong incentives for national stakeholders, since significant benefits through the implemented environmentally sound technologies (EST) are mandatory result for the user. At the same time, the interests of technology providers must be kept. The procurement of technologies is performed via credits taken by users. However, assistance is given by the local CPC to acquire a sound basis for the latter. Furthermore, when transferring a technology local conditions like human and financial capacity, legal frameworks, and working environment must be respected (LCPC, 2002).

The diffusion of ESTs as shown in Figure 9 is a key element for the improvement of productivity in a sustainable manner. Accordingly, a package of supportive policies, investments or business cooperation and a holistic approach should enable this process. Supportive policies that offer further incentives and promote the application of ESTs are as important as ensuring the proper basis for conferring credits for investments in those technologies. “Life cycle perspective” means the extension of the traditional focus on

the improvement of processes regarding environmental aspects and productivity on short term but the environmental impact of a technology during and after the entire life cycle.

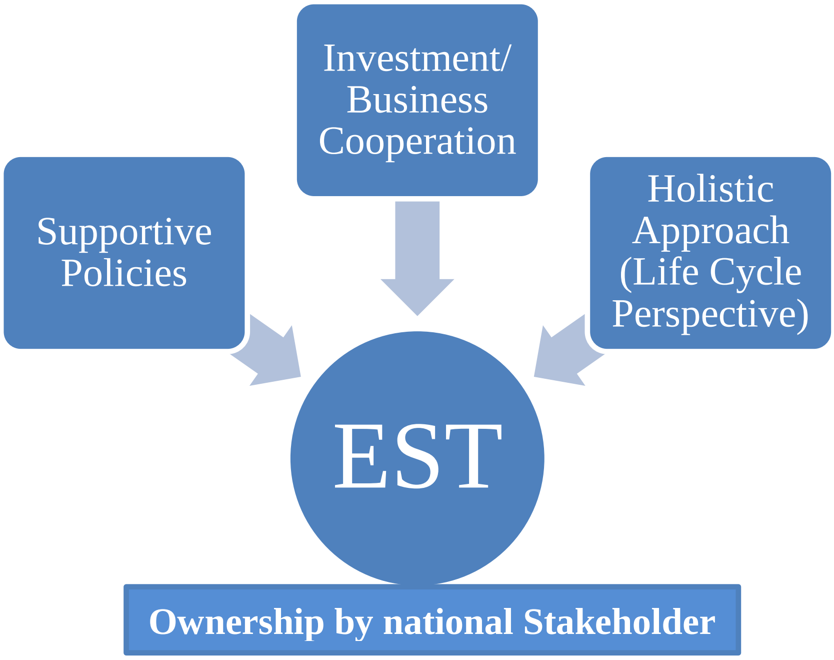


Figure 9: EST Diffusion

Source: (UNEP, 2002)

The term "Investment/ Business cooperation" considers that the effective transfer of ESTs requires the preparation of bankable investment projects. Thereto, either existing financial mechanisms are utilized or the establishment of specific credit lines for EST supported. "Supportive Policies" incorporate the existence of incentives and further supporting mechanisms. In this context, the EST transfer at company level is supported by the national CPC (UNEP, 2002).

Outcome

Since classical mechanisms (laws, regulations, social pressure) are weak in Lebanon, projects respecting interests of individual companies (mostly monetary) realistic and possibly running for long time. CP can be categorized as a policy instrument utilizing

incentives through technology transfer, which acknowledges and supports interests of individual companies.

3.8.2. Technology Transfer: Solvent Recycling

The technology transfer of solvent recycling poses a win-win situation for industry and environment. While the interests of individual companies are respected, negative environmental impacts are mitigated. Participants become aware that what they consider as waste is a valuable resource that can be used several times. As elaborated further in chapter 5.4, the participating company can profit significantly in monetary terms when recycling used solvents instead of discharging them to the environment. Furthermore, they can improve the company´s reputation as environmentally friendly working and as contributing actively to the protection of the local water resources.

In addition, when fewer contaminants are released to the environment, costs of environmental degradation are reduced. This might at the end also affect the individual company positively.

Larger companies become internationally more competitive if production and efficiency of resource use is raised. They could export abroad and thus benefit from the indirect subsidies that the European Union (EU) offers them. Since 2002 Lebanese products can be exported tax free to European countries (EU, 2002).

In case of on-spot solvent recycling, literally technology transfer would apply if acquiring a recycling unit. In case of participation in a recycling service, knowledge transfer would be performed in form of raising awareness. Furthermore, a possibly established company hosting the recycling service, EST would be purchased.

3.8.3. Introduction of Vacuum-Distillation

Distillation is a thermal process that is utilized to separate liquids with differing boiling points. The liquid with the lower boiling point is mostly the material in focus and can be re-used after distilling. This cleaned material is called distillate. The liquid with the greater boiling point remains in the distillation unit and is discharged after processing. It is called residue.

Background

The kinetic energy of molecules within a material is directly related to the thermal energy that has been applied to it. In the frozen phase molecules are packed at the rate of highest density – except of ice – and hold the lowest kinetic energy. When thermal energy is added the frozen material starts melting and converts into the liquid phase. In this phase molecules are packed less dense and kinetic energy is greater. Hence, due to more space and greater energy the molecules are now enabled to move relatively freely. The more heat is added, the higher the kinetic energy gets and thereby the movement of the molecules is increasing.

Each material, liquid or solid, possesses a certain vapor pressure at a certain temperature. That means, according to the rate of their kinetic energy, molecules escape as vapor to the surrounding atmosphere. As long as the atmospheric pressure is greater than the vapor pressure, most of the molecules are pushed back to the (mostly) liquid phase.

The boiling point of a liquid is reached when the vapor pressure equals the surrounding pressure. Consequently, experiencing no pushing back anymore, the molecules can escape freely from the liquid phase to the surrounding.

Reverse concluding it is to state, if the surrounding pressure is lowered, liquids can be evaporated freely at lower temperatures.

One example: Water evaporates under atmospheric pressure (1 bar) at 100°C. If the surrounding pressure gets reduced to 500 mbar a temperature of only about 80 °C is required to boil the water.

Vacuum-Distillation

If the total pressure in a system is lower than 1 bar the system stands under vacuum.

In Figure 10 the flow scheme of the vacuum-distillation unit that is chosen for the solvent recycling service is illustrated. The Evaporator and the Condenser stand under a vacuum of 200 $mbar_{abs}$. The vacuum is maintained by the liquid ring vacuum pump that is placed behind the condenser.

The used solvent is filled into the Evaporator periodically. The solvent is heated up indirectly by the Support Heater. The existing vacuum allows the solvent to evaporate at low temperatures. The material with the higher boiling point is remaining in the lower part of the Evaporator and is discharged automatically after some processing time by the Sludge Conveyance Pump. The solvent vapor is sucked into the Condenser where it transforms into the liquid phase. As liquid it is conveyed by the liquid ring vacuum pump into a tank from where it is ready for use.

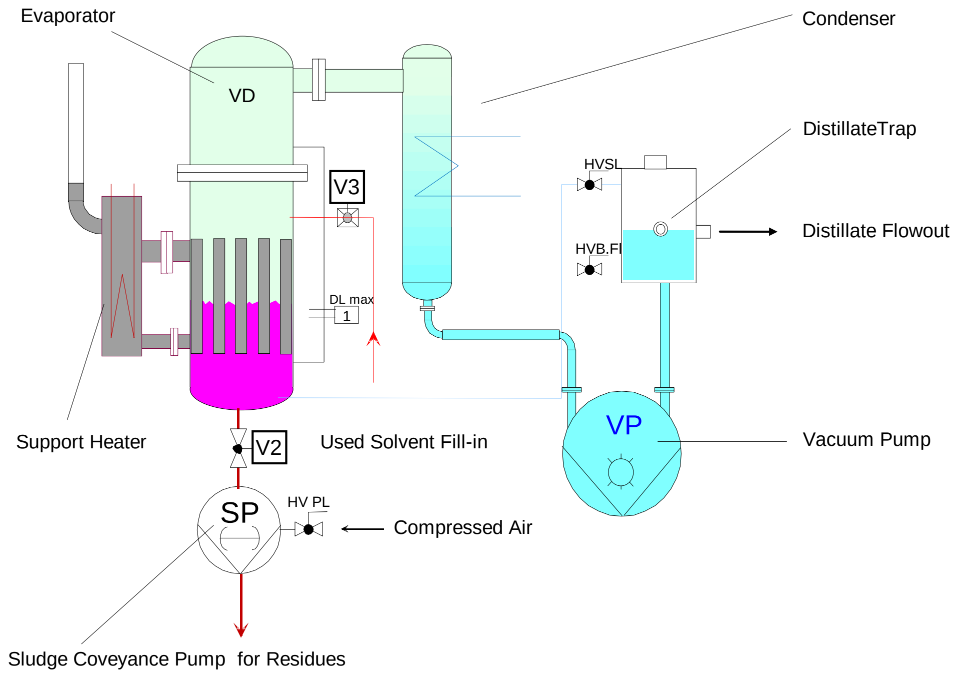


Figure 10: Flow Scheme of Vacuum-Distillation Unit DESTA 20

4. Methodology

4.1. Concept of Integrated Water Resources Management (IWRM)

The umbrella of the thesis conducted is the concept of Integrated Water Resource Management (IWRM) as defined by the Global Water Partnership (GWP): "*a process that promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems"*(GWP, 2000, p. 22).

The four pillars of the concept include the acknowledgment of water being a finite and vulnerable resource, while its management requires the firm involvement and participation of the stakeholders. Furthermore, adequate integration of women in the decision making process and management of water resources is mandatory. Finally, water is recognized as economic good, which is demanded for a sustainable development and efficient application (GWP, 2000).

Especially the involvement of stakeholders is reflected in this research. In the current case, most influencing stakeholders are identified as the local industry. Their involvement and acknowledgment of the necessity of cleaner production for reaching the prevention of water pollution is essential.

4.2. River Basin Concept

The river basin concept includes the definition of a watershed as *"geographic area [...] within [...] limits of a system of streams and rivers converging toward the same terminus, generally the sea or sometimes an inland water body".* (Molle, 2009, pp. 484-494). In this context, the study assumes that pollutants discharged by industries will

affect surface and groundwater of the watershed as they travel the same paths taken by precipitation. Hence, pollutants will enter water bodies that are either determined for human consumption or contribute to rivers and the Mediterranean Sea.

4.3. Sources of Information

Different methods have been applied to assess the situation of industries in the Nahr El Kalb (NEK) Watershed. Secondary data referring to the study area and Lebanon as total was obtained by online research via ScienceDirect, Scopus, Springerlink, and googlescholar. Furthermore, reports were assessed by the website of the Ministry of Environment, Lebanon (MoE), the German organization of Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), and by contacting authors of this sector.

Information referring to possible impacts on environment, aquatic life, and level of toxicity of expected solvents has been compiled from safety data sheets of various sources.

Additionally, to gain a good insight view of the presence of industries in the district of Kessrwan in the NEK Watershed personal conversation has been held with staff of the concerned municipalities, as well as the manager of the responsible water treatment plant. The contact to those institutions was partly arranged with the help of the BGR. A list of existing industries in the industrial zone of Zouk Mosbeh has been supplemented with companies identified during field visits in this area.

A questionnaire was conducted among the focused industries. Thereby, the real perception from industry of “cleaner production” methods and the readiness of these stakeholders towards the participation and implementation of the proposed mitigation method was assessed.

Answers collected at these industries were discussed with external experts of each branch. It was checked whether the gathered replies comply with common practices and reflect the real situation. It had to be considered that industries fear environmental regulations in form of restrictions and tend to underestimate amounts of solvents used. These amounts were adjusted to what was meant to reflect the real situation with the support of the experts of each branch.

In addition, confidential information from a company that is already implementing the proposed recycling unit was gathered. This helped to evaluate further the results of the conducted questionnaire as well as estimating quantities of total usage within the NEK Watershed.

4.4. Questionnaire

The conducted questionnaire serves the aim to verify or falsify two underlying hypothesis. While the first hypothesis refers to a general question about the whereabouts of used solvents, the second hypothesis takes socio-economic aspects into account. An example of the questionnaire sheet in English and Arabic is attached in Annex IV.

Hypothesis 1:

Solvents are dumped after use.

Hypothesis 2:

With adequate economic incentive industries are willing to recycle used solvents. Be it by implementing of on-site solvent recycling or participating in an outsourced recycling program.

In addition, the conducted questionnaire shall help to identify and quantify solvents used in the concerned industries. Local prices for solvents as stated by questioned

parties shall further support the cost/benefit calculations of an exemplary business plan for a solvent recycling service company in Lebanon. Consequently, collected information about readiness expressed by companies to participate in such recycling service shall support the development of strategies for the implementation of service schemes. Based on the prices for solvents as given by industries and estimated sound per liter prices for recovered solvents by the service, possible monetary benefits for industries when participating in recycling services have been calculated.

The structure of the questionnaire follows the guidelines as given by Peter Atteslander in his book “Methoden der empirischen Sozialforschung” (engl.: Methods of empirical social research). While the participants have to fill out the questionnaire, an administrator will attend. Thus, occurring obscurities can be clarified. It is outmost important that the participant does not get influenced by the administrator.

According to the situation, the questionnaire has been conducted in English or in Arabic. The current questionnaire could be answered in 20 minutes completely. Up to 20 questions have to be answered. The questionnaire contains one sequence of ten matrix questions that have to be answered by yes or no. Thus, those questions are classified as closed end questions. Furthermore the questionnaire contains contingency questions, which have only to be answered if a previous, conditional question had a positive or negative response. Ten of the 20 questions are open ended. They are either completely unstructured where the participant is free in his answer, or he has to name quantities of certain used materials.

Usually the required sample size for achieving reliable results must be determined before conducting the questionnaire. The sample size is related to the number of total possible stakeholders of the focused group of SUI. However, since no reliable

information was available regarding the exact number of industries existing, it was attempted to distribute as many questionnaires as possible.

The questionnaire has been conducted over a period of two months (September 2010 to October 2010) and included 16 companies of six different branches. However, only five of these six were chosen for deeper evaluation. The focused branches are the priory discussed industries of Printing & Packaging, companies with Smaller Printing Presses, Paint Producers, Car Paint Shops, and Dry Cleaners.

5. Results and Discussion

5.1. Questionnaire Conducted at Local SUI

Evaluation of Questionnaire

The questionnaire has been conducted over a period of two months (September 2010 to October 2010) and included 16 companies of six different branches. However, only five of these six were chosen for deeper evaluation. The focused branches are the priory discussed industries of Printing & Packaging, companies with Smaller Printing Presses, Paint Producers, Car Paint Shops, and Dry Cleaners. An example of the distributed questionnaire is attached in Annex IV. For the industry specific application of solvents, please refer to chapter 5.3.

With the exception of one company, the questionnaire has been appreciated and information has been given voluntarily. Nevertheless, numbers given referring to the applied amounts of solvents indicate general tendencies but are thought to be underestimated. However, after comparing information given by several companies of the same branch, and after discussion with external experts of the certain sectors amounts of solvents were identified that are meant to reflect reality. These numbers are presented in chapter 5.2 in Table 19.

Moreover, several questioned companies denied totally the usage or the existence of residues of solvents at their company. After discussing this issue with further external experts it must be stated that this information is not realistic. Consequently, for the concerned companies typical average amounts were assumed for identifying the prior mentioned numbers.

According to Angela Akl, field coordinator at the Environmental Fund for Lebanon, companies of the researched branches are afraid of giving accurate numbers referring to

materials that might be harmful for environment. It is meant that they fear negative consequence resulting from their openness in terms of stricter controlling of compliance to Lebanese environmental regulations.

Out of the 16 companies visited, 14 answered the questionnaire, while three denied the use of solvents and one the existence of solvent residues. The parties denying the solvent use are two companies of the branch of Paint Producers and one Smaller Printing Press runner.

The Printing Press runner claimed to clean his machine with water while using solvent-based ink. This is chemically not possible and thus this information was interpreted as incorrect. Nevertheless, due to the impression gained at this company and in comparison to a further company interviewed of this sector, a quantity of 30 l solvent per month have been assumed to be applied for cleaning purposes.

The justification of the two Paint Producers for their denial of using solvents was the exclusive production of water-based paints and inks. Thus, they would clean their mixing drums and tools only by water. Theoretically, this is possible. However, solvents have much better cleaning characteristics than water. Moreover, cleaning by water requires excessive quantities and further manual post processing. According to the division head of a German company for water-based inks, up to a 25 times higher quantity must be applied when using water instead of solvents as cleaning agents, depending on the characteristics of a certain ink,.

Furthermore, the water utilized is then contaminated with pigments and its treatment is complex and expensive. Conversely, used solvents could be recovered easily and pigments eventually get re-used. Hence, the application of solvents poses a much more environmental friendly and cost-efficient alternative to the usage of water. In addition,

due to the better cleaning characteristics, the total time spent on cleaning is much shorter when utilizing solvents instead of water.

Besides technical constraints, the application of water as cleaning agent poses hygienic problems. Water-based inks that are designed for the application on packaging for the food industry must fulfill high hygienic standards. Since water is always a potential carrier of bacteria, cleaning actions of mixing drums etc. should always be performed with solvents. Thereby, eventual bacteriological contamination should be prevented. However, the warm Lebanese summer months provide best conditions for fast bacteriological growth. Consequently, if cleaning actions are truthfully performed with water, contamination of inks is likely and thus the fulfillment of possibly requested hygienic standards not given(Dr. Lauber, pers. comm.)

Photos of cleaning agent discharges from paint producers are attached in the Annex I.

The company that denies the existence of solvent residues is from the sector of Dry Cleaners. It is claimed that the internal recycling (see more chapter 5.3) of the washing machines is actually that efficient that no sludge containing solvent, grease and tilt but only dry powder remains as residue. However, after proofing this information with an expert of this field, this statement must be considered as untrue. Hence, the quantity of solvent usage as stated by another questioned dry cleaner was chosen for identifying the actual per month solvent consumption of the first mentioned. It is estimated to be around 50 l monthly

All respondent companies, except one, are willing to participate in the solvent recycling service. However, all companies are interested in reducing their costs for solvents, even though monthly expenses might be relatively low in e.g. individual small scale companies. Currently, only one of the participants is giving back the used material to

his solvent distributer. All further companies dispose their material either aside domestic waste or, what applies to one-soul companies, directly to the environment. However, as quantities of monthly used solvents are high in the sectors of Printing & Packaging and Paint Producers, the claimed strategy of disposal with domestic waste might differ from the actual.

All questioned parties are familiar with the term of recycling and its meaning. Moreover, cleaner production resulting from recycling is assumed by the vast majority as cost saving rather than costs causing action. Only two of the questioned companies are not aware of negative impacts posed by the disposal of used solvents to the environment. However, it is not clear whether they are truly unaware or simply deny its harmful characteristics. Nevertheless, environmental impacts might be underestimated as expressed by the statement of one Paint Producer, who felt comfortable with his practice of discharging about 20 l daily of mixed solvents and paint components to the environment.

Outcome

The results of the conducted questionnaire clearly state a positive overall response. It was identified that companies of same branches use same solvents. This eases the management of an eventual recycling service significantly and furthermore enhances cost efficient performance of recycling. However, so far no explicit recycling service is existent, only minor on-spot recycling and re-use is performed. Negative expectations regarding solvent recycling are very limited and only refer to possible quality losses of the recovered product.

In this context it can be stated that both, hypothesis 1 and hypothesis 2 are verified. Used solvents are dumped by all questioned parties but one and furthermore all

questioned parties but one would change their behavior in terms of collecting the used material for being available for recycling.

5.2. Estimation of Quantity of Used Solvents in the NEK Watershed

Based on the questionnaire that has been conducted during this research, an estimation of used solvents available on monthly basis in the area of Kessrwan in the NEK Watershed is attempted. For this purpose, not the actual numbers given by the respondents will be taken into account, but rather numbers that meet more realistic conditions. During the interviews candidates mostly underestimated the quantity of their used solvents or denied totally its existence. After discussions with experts quantities for each industries has been set as seen in Table 19.

Table 19: Estimated Quantities of Used Solvents available in Kessrwan

Business	Quantity of Used Solvent [l/month]	No. of Branches	Total Quantity [l/month]
Smaller Printing Presses	50	3	150
Printing and Packaging (Roto & Flexo)	150 (x2)[1]	10	3,000
Printing and Packaging (Off-Set)	400	1	400
Paint Production	1200	7	8,400
Car Paint Shops	20	22	440
Dry Cleaner	16.67 (x1.5)[2]	5	125
	Total Quantity		**12,515**

The total quantities of used solvents as shown in Table 19 are calculated on the basis of a week with six working days. Projecting the total monthly quantity for the entire year an amount of approximately 150.2 t of used solvents that is potentially threatening the environment would result. Taking into consideration that Zouk Mosbeh has a significant share of the country´s total industrial zone and that the total estimated quantity for the

[1] Assumed that one machine requires 150 l/month of cleaning solvent and that on average each company has two printing machines
[2] Assumed that one machine has 16.67 l/month losses in form of residues and that on average each company has 1.5 dry cleaners

entire country lays at around 940 t/year (El-Fadel, Zeinati, El-Jisr, & Jamali, 2001a) the projected number appears very realistic.

However, the stated number is not equal with the number of used solvents affecting the watershed´s environment, but rather states the potential threat. According to the results of the questionnaire, companies have five strategies of how to handle the waste: A small minority recycles the used solvents, and others reduce the amount of waste by re-using the solvents for other processes. This mostly happens in the Paint Producers sector. Nevertheless, the quantity stated in Table 19 has taken these waste reducing actions already into account. The most common strategy - as stated by the respondents - is the disposal of used solvents with domestic waste. This is done due to the lack of the alternative of separate industrial waste disposal/treatment. Printing as well as Printing & Packaging companies nearly all follow this strategy. Thereby, the used solvents get eventually transported out of the NEK Watershed and disposed of aside domestic waste on landfills.

Only one Printing &Packaging company is known that is storing its used solvents since several years in barrels and now finally has bought a distillation unit for recycling the collected material. Since nearly all Car Paint Shops are of a very small scale, they do not have the capacity of treating used solvents. The quantities occurring in this sector seem to be so low for the single shops that a treatment or even only collection did appear to them, yet. Common practice in this branch is to dispose everything directly to the soil. Only one exception could be stated. The Car Paint Shop interviewed with the highest number of employees collects its used solvents and returns it to its solvents supplier where it most likely gets recycled.

Outcome

Nevertheless, taking into account that each company follows a slightly different strategy of disposing its waste and furthermore taking into account that eventually not all companies stated their exact procedure of waste disposal, it is not possible to state the precise amount of solvents affecting the area´s environment. However, if only a fraction of the roughly estimated 12.5 t/month reach the water bodies severe effects on human health, wildlife, and water quality could be expected.

5.3. Solvent Recycling According to Branch

Paint Producers

Solvents recovered from paint producers found their prior application as cleaning agents for mixing drums or similar and instruments and tools. According to its needs, the solvent of required cleaning purposes is chosen. Solvents with high cleaning purpose are of high quality and thus high price. Hence, applications that are manageable with solvents of lower cleaning characteristics will be performed on lowest cost basis. The viscosity of used material originating from Paint Producers is most probable very low and thus the material itself easily to handle. This excludes the requirement of further precautions for processing while recycling. However, a mixture of paints and inks designed for various uses and with different properties might be contained. Consequently, the re-use of the residues from the distillation process might be critical, if possible at all for low quality applications.

Printing & Packaging

This industry uses a variety of solvents. Some fulfill the role of a thinner, others are used for cleaning purposes. However, during the printing process, solvents are acting as a pigment carrier. The pigment-solvent solution is placed in drums from where they are

delivered to the pipes and then cylinders where the actual printing happens. After the ink has been printed on the desired material, like cardboards or plastic films, the process step of drying follows. In this step, the solvent that carried the pigment is evaporated and the pigment binds with the material it is printed on. If a job change happens and hence other colors want to be printed, the entire piping system and cylinders must be cleaned from the previous color. Solvents with strong cleaning purposes find their application in this step. A mixture of ink, thinner-solvent, and cleaning solvent results. With vacuum distillation, this mixture is easily to separate into ink and solvent. The different solvents will still be mixed. However, this mixture does not constraint the re-use of the recovered solvent as thinner or for first cleaning applications. The residue in this distillation process will be mixed ink. As vacuum distillation applies only very low temperatures to the material, ink characteristics are not modified and thus can be re-used as ink. This is possible by adding darker pigments to the solution or using it directly without any further measure as the color appears.

Dry Cleaner

Predominantly the solvent of Perchlorethylene (PER) and Trichlorethylene (TRI) finds its application in the sector of Dry Cleaners. During the normal process, the solvent is enriched with detergents. The solvent is responsible for removing grease and oily impurities from the cloths and the detergents remove every defilement that is not on oil-basis. Thereby, the solvent furthermore takes up tilt from cloths. Thereby, a mixture of solvent, tilt, grease, and detergents results.

Nearly all dry cleaning machines do possess an internal solvent recycling that is based on distillation. However, all dry cleaning machines work during their distillation under atmospheric pressure. This makes the application of very high temperatures necessary.

The higher the applied temperature, the higher the stress put on the solvent. If a certain temperature is exceeded, the solvent gets damaged which can result in acidification of the material. Moreover, this would lead to corrosion and thus damages to the cleaning machine. Operators do utilize high temperature to decrease the ratio of solvent remaining in the residue. However, necessary temperatures can be reduced significantly by utilizing vacuum distillation. Thus, the process of acidification can be prevented. Nevertheless, if this solvent was processed without any further modification, percentages of solvent in the sludge would remain high. Hence, it is recommended to dilute the material to process in oil. Any oil would be suitable and there are no further requirements regarding its quality.

For the process of the proposed vacuum recycling unit it is important to have a fluid as residue that is conveyable easily by a pump.

If diluting the mixture of tilt, grease, detergents, and solvent in oil, the oil becomes the residue that binds the tilt, grease and detergent and thus the solvent can evaporate freely. While formerly solvent kept the sludge semi fluid, oil must supplement it to ensure the ability of processing it.

However, the percentage of solvent remaining in the residue can be reduced to 2 % at least, but most likely even less.

The predominant component in the residue will be oil. However, save handling of this should be ensured and save possible applications evaluated. One solution might be the utilization of its high caloric energy which could find its application in cement factories for incineration. However, even if the resulting oily sludge could not be processed safely further within Lebanon, a reduction of potential water pollution has been gained, since oily sludge has less impact on environment that PER or TRI. Furthermore, the

resulting sludge can be stored easily until an adequate solution for its responsible treatment is found.

5.4. Advantages of Solvent Recycling for the Industry

The questionnaire conducted for this thesis clearly states that the positive monetary reward is important for the success of a solvent recycling service. Thereby it is not essential that the participants get great revenues out of the recycling, but rather that it poses a higher attractive alternative to the disposal of the used solvents.

However, the monetary benefits for each sector shall be illustrated by the following. Calculations have been made based on the solvent quantities as stated in chapter 5.2 and prices that were given by interviewees. Condition for achieving the stated recovery efficiencies is the correct storage of the used solvent, which means the covering of storage containers to prevent evaporation. Table 20 summarizes the average of potential monthly savings per work shop if participating in a solvent recycling service. The columns of “Price (recov.)” and “Paid for Recovery” mean the price taken by the recycling company. The recycling company charges the participant for entire the quantity of used solvent he hands in. After recycling, the recycler gives back the recovered material for free to the participant. For detailed description of the recycling scheme, please see chapter 5.6. Prices indicated in the table are a first estimation of prices accepted by potential customers and feasible for the recycler.

Table 20: Average of potential monthly monetary savings per workshop

Business	Quantity [l/month]	Price (fresh) [$/l]	Quantity Recovered [l/month]	Price (recov.) [$/l]	Paid for Recovery [$/month]	Potential Savings [$/month]	Potential Savings [$/year]
Paint/Ink Manufacturer	1,200	1.60	1,080.00	0.95	1,140.00	588.00	7,056.00
Printing & Packaging	300	2.50	270.00	1.20	390.00	360.00	4,320.00
Printing	50	2.00	N.A.	N.A.	N.A.	N.A.	N.A.
Car Paint Shops	20	2.00	16.00	0.80	16.00	16.00	192.00
Dry Cleaner	25	5.00	23.52	2.50	70.00	47.60	571.20

Paint/Ink Producers

A slight modification of handling is conditioned for the successful recycling of solvents in this sector. Currently paint producers use a variety of solvents, according to their needs. For each application they use the lowest quality - and by that the cheapest - of solvents fulfilling the requirements. This practice results in a mixture of various solvents in the waste, which makes the distillation and thus the recycling of this material less efficient.

However, it is recommended to reduce the number of solvents and switch – if possible in this sector – to one solvent that has best cleaning characteristics and thus can be applied for all demands. Although this material might be the most expensive money will be saved, since this one defined solvent is easily recoverable and only losses due to evaporation must be supplemented.

Based on the information collected by the conducted questionnaire, an average price of 1.60 $ per liter is assumed for the solvents that are currently used in this sector for cleaning purposes. Based on the numbers of chapter 5.2 and an assumed recovery rate of 90 % monthly savings of 588.00 $ could be achieved at each work shop. Additional revenues from the re-use of the residues from the distillation process as low quality ink might be possible.

Printing & Packaging

Alike the paint producers, the sector of printing & packaging utilizes a number of solvents for different purposes. However, the applied solvents are similar in characteristics and the resulting mixture can be recovered and re-used without major constraints. The recovery efficiency with proper handling is estimated at 90 %. Hence, monthly savings in terms of cleaning solvents are estimated to reach 360.00 $.

Unlike the paint/ink producer, who deals with paints and inks for various uses and purposes, companies of printing & packaging only process inks that are designed for their usage. Hence, the intermixture of inks with unsuitable properties that could restrict the total re-use cannot happen. Consequently, the printing and packaging industry could gain additional revenue from the direct re-use of the residues as ink for dark color applications.

Smaller Printing Presses

Currently, printing companies with smaller presses use gasoline as cleaning agents. This material is not recyclable easily due to its high boiling point. Main reason for its usage might be its permanent availability and relatively low price. However, it is recommended to switch to a solvent that is to process easily and yet fulfills all requirements. No information is currently available of which solvent could be suitable and how complex the recycling or the efficiency rate of recovery would be. If assumed that the supplemented solvent is recoverable to 90 % and an average price of 1.00 $ was taken for the delivered used material, savings of roughly 40 $ monthly could be achieved compared to the current price paid. These assumptions are not mentioned in Table 20, since they are only of notional nature.

Car Paint Shops

Due to the use of curing agents, recovery rate of solvents in the branch of Car Paint shops is lower than in other SUIs. Curing agents have the purpose of quick drying and proper hardening once the lacquer or paint is applied. If solvents containing this curing agent are collected, jelly material will build up after time at the bottom of the storage container. This restricts the full recovery of the solvents. Therefore, an efficiency rate for recovery of 80 % is expected. The price to pay for the material delivered to the recycler is low compared to the prices taken for the recycling of material from other SUIs. The low price originates from the intension to provide further monetary incentive to promote the recycling of solvents among this industry and to raise the benefits for the participant. Consequently, each work shop would save on average 16 $ monthly. Although this still might appear as relatively low revenue, it must be considered that the vast majority of car paint shops are one-soul companies. Hence, total budgets of these companies are much smaller compared to other industries and thus the small revenue of 16 $ monthly can already pose a convincing incentive.

Dry Cleaner

The process of recovering solvents from this type of application is slightly more complicated compared to the others. However, although quantities of wasted solvents are low reasonable monetary savings by its recovery are possible, which makes recycling attractive for the participant.

Additionally to the benefit of solvent recovery by an external party, a second, technical advantage is to mention, if the solvents of PER or TRI find their application. Dry cleaning machines already do have a built-in internal recycling. This recycling is relying on atmospheric distillation, which has as residue sludge of lint, grease, and detergents. It

further contains high percentages of solvent. However, during the progressing process of internal recycling, temperature must be increased to very high extend for decreasing the solvent content in the sludge to the lowest, with atmospheric distillation possible rate. By doing so the solvent gets probably severely overheated which results in its acidification. For preventing damages to the machine stabilizers must be added for deactivating the accruing acid. This stabilizer is very expensive and reaches prices of 25 $ per liter. The process of vacuum distillation requires only low temperatures, which allows very smooth recycling of solvents and thus does not initiate its acidification.

It is recommended that dry cleaners only do a very short internal recycling. Thus, the solvent would not be exposed to overheating for a long time and hence the possibility of acidification would be reduced. The residues with high fraction of solvent will be recycled, and the solvent will be recovered to approx. 98 %. Hence, dry cleaners will reduce the costs due to the reduction of solvents waste and the reduced application of stabilizer.

Non-monetary Benefits

Non-monetary benefits were not elaborated too broadly by the questioned parties. The only advantages mentioned, besides monetary, is to stop the disposal of wastes to the environment and sea, and thus working more environmental friendly.

However, the named advantages are no striking arguments and hardly could singly convince candidates to the participation in a recycling service. Moreover, it is not clear whether these advantages were mentioned out of persuasion or out of the belief that they might be the correct required answers. Yet, some questioned parties even named no benefits at all besides monetary and denied any negative impact on environment of their solvent waste.

Common Practice

A common measure of solvent reducing action in the sector of Printing & Packaging as well as in the sector of Paint Producers is to re-use the solvents that have been utilized for the cleaning of bright color applications in cleaning action of following darker colors. This measure requires storage space and means extra work load. Solvents must be put into barrels after first time use, must be stored and probably labeled, and finally before re-using the solvents must be pumped again from the storage barrel.

Reported Experience

One non-monetary advantage of solvent recycling that was stated in an interview conducted with a company that already utilizes vacuum distillation for solvent recovery is the less space required for storing fresh and used solvents. This might be a convincing argument for further companies when promoting the participation in the solvent recycling service.

5.5. Advantages of Solvent Recycling for Environment and Government

Governmental Side

Various direct and indirect advantages arise for the Lebanese government from the implementation of and potential involvement in a solvent recycling service.

As elaborated in earlier chapters, priority for the Lebanese government is to strengthen the economy and industry for reasons of social stability and prosperity. Due to the reduction of monthly fixed costs, capacities are freed and thus available for further investment or even employment. Hence, monetary benefits gained in industries by solvent recycling are in-line with this interest.

Industrial waste does not undergo a specific treatment but is handled together with domestic waste (El-Fadel, Zeinati, El-Jisr, & Jamali, 2001a). The emptying of waste containers is frequently performed by the municipal workers by hand. As industries dispose their partly hazardous wastes in buckets and bags into these waste containers, an exclusion of this waste to domestic waste means a protection of municipal workers towards these materials. As municipal workers are employed at the government, it is assumed that also the government is responsible for their work place safety.

Environmental degradation causes each year profound costs to the entire country. Chapter 3.6elaborates on the costs and lost benefits resulting from dropping workforce due to diseases and mitigation measures originating from environmental pollution. As pollutants stress human health and environment its reduction should lead to a decrease of costs for environmental degradation.

One mitigation measure for environmental degradation is the installation of wastewater treatment plants. Currently, the responsible institutions are in the hot planning phase for construction of one treatment plant for the NEK Watershed. Correspondently, the ration and kind of contaminants of the inflow shape the complexity of treatment and achievable quality of the outflow. The costs of the chosen technology are directly related to these determinants.

The installation of an intervention in projects for cleaner production has positive impact on image of Lebanon and might attract further investments and funding for similar project from foreign organizations. Furthermore, several trade agreements Lebanon conducted internationally bind the country to an improvement of product quality and environmental performance (MoE, 2001).

Supporting initiatives like the solvent recycling service, which can convince with monetary benefits for participants and environmental improvements for society, could reduce large investments of the government into environmental awareness campaigns. However, due to the lack financial resources it is probable that no budget for awareness campaigns can be allocated during the next years. Consequently, projects like the described recycling service might be one of the few instruments available for the government reaching industries at all.

At any rate, if the industrial sector continues its expansion, sooner or later the government must provide a solution for sufficient and sustainable industrial waste management. The solvent recycling service means a reduction of industrial liquid waste and thus takes over partly what is governmental responsibility. This should be acknowledge and hence receive its adequate support.

Environmental Side

The benefit of the environment arises from the reduction of pollutants discharged to soil and hence water bodies. Thus, land and sea related environmental degradation might be reduced and ecosystems thereby preserved. Furthermore, stress on groundwater quality might be reduced with the reduction of contaminants added to the soil.

5.6. Design of a Recycling Service

The questionnaire that was conducted among the targeted industry clearly shows that all questioned parties are interested in participating in a solvent recycling service but only a minority is interested in actually purchasing their own recycling unit. This is rooted in the little quantities of used solvents that accrue in the small scaled companies. Hence, by the following paragraph a possible design of a solvent recycling service shall be illustrated.

For guaranteeing certain quality standards and assuring that the participants are provided with the solvent that has the required characteristics for their application, each participant will receive back only the cleaned material that results from distilling his used solvents. Thus, no mixing with other solvents is secured. The participant can store his used solvent in any safe and sealable container. Nevertheless, the container size is limited to a certain volume. For keeping the costs of the recycling service low all containers should be limited to a volume that can be lifted by hand and do not require additional machinery. Hence, for the time being the maximum size of one container is limited to 30l, since it is believed that this is the greatest weight that one worker can elevate.

The participant will be charged for the entire quantity of used material he hands in. He will receive back the full recovered quantity of solvent free. If desired, the participant will also receive back its residues. This could appear in the case of the printing& packaging industry as well as in the branch of paint producers where the residues are actually just mixed ink which could be re-used after adding darker pigments as darker ink or paint. The price charged per liter of material handed in will be linked to its viscosity and the complexity of recovering it. The higher viscose the material is the less solvent is expected to be contained. Thus, the higher the viscosity of handed in material, the higher the price charged per liter. This is meant to be a protection measure for the recycler. Many companies there used solvents in barrels since years. It is probable that most of the once contained solvent has evaporated over time. If now the participant would hand in this material and the recycler would charge only for the material recovered, he might end up with a very high quantity of non-usable material he has to dispose and only a very little quantity of solvent he can charge for.

After the recycling of the used solvent the participant receives back the empty container that could be re-used for storing the further accruing used solvents.

The recycled solvent is returned back to the participant in clean containers. Each container gets labeled with the individual participant number. By this, confusion with the material from other participants shall be avoided.

The numbering of customers and labeling of the containers furthermore allows to store the recycled material for a certain time and to deliver it later in groups. By doing so, the costs of distribution shall be reduced.

A small transporter picks up the containers filled with used solvents from the participant upon request. If participants can predict their accruing quantities of used solvents, fixed dates of collection can be arranged.

5.7. Business Plan for a Recycling Company

A general partnership has been chosen as legal form for the company for the illustration of this exemplary business plan. In this business form a minimum of 2 partners are required, while no minimum capital must be available as deposit. The involved partners are jointly and severally liable for debts on their assets. The fixed cost of registration is LBP 1,250,000 which equals about 830 $ (SA, 2010).

Since the technology transfer as described in prior chapters might result in foreign investment, some country specific regulations must be respected when establishing this enterprise of a solvent recycling service. Accordingly, the foreign investor must always have a Lebanese partner and can hold most shares, but never more than 49 % of the total. Thus, in case of two partners, the Lebanese partner would hold 51 % and the

foreign investor 49 %. In the case of three partners, the foreign investor could keep his 49 % and the two further Lebanese partners would share the remaining 51 %.

The actual set up of a company in Lebanon is relatively easy and thus can be performed within a week. The incorporation formalities are very simplified and the Investment Development Authority issues all the necessary authorizations. The registration must be done in the place where the headquarter of the company is located (SA, 2010).

The business plan as illustrated in the following paragraph has been conducted for the specific case of investment in Lebanon. It is respecting the condition that a credit was used to finance initial investment and first months in which cost recovery by turnover might not be given. An estimation of the amount of initial investment and monthly costs are illustrated in **Error! Reference source not found.**. The actual estimated investment lies at about 36,500 $ and monthly costs at about 4,000 $ plus the monthly financing costs. The financing costs vary from one month to another, since they depend on the residual debt. However, a credit of 63,000 $ is drawn on for financing eventual deficits from first months of establishment.

Table 21: Costs of Estimated Initial Investment and Monthly Costs

Investment Item	**Cost**	**Fixed Cost**	**Amount**	**Estimated Average Variable Costs**	**Amount**
Car for transportation (used)	6,000 $	Rent	400 $	Gasoline (car)	250 $
Distillation unit	25,000 $	Wage worker	600 $	Gasoline (generator)	250 $
50 times 20 l container	165 $	Wage guard	400 $	Electricity	100 $
Back-up generator	1,000 $	Wage Partner 1	1,000 $	Water	10 $
Shelves for work shop	300 $	Wage Partner 2	500 $	Overhead	500 $
Office equipment	1,000 $	Interest Credit (Average year 1-5)	2,015 $		
Registration fees	830 $				
Overhead	2,170 $				
Total Investment	**36,465 $**	**Sub-Total**	**2,900 $**	**Sub-Total**	**1,110**
		Total (year 1-5):	**6,025 $; Total (year 6-12): 4010 $**		

The calculatory interest rate for the used credit is 6 % and payback stretches throughout a period of five years. Assets like the distillation unit and a needed car are depreciated linearly, by 12 and 6 years.

Companies of the legal form of general partnerships pay taxes on profits on a progressive scale. From a profit level from 36,000 $ to 69,333 $ (54,000,000 LBP to 104,000,000 LBP) a tax rate of 16 % is imposed. However, profits can be lowered by all expenses emerging from the company´s operations (PKF, 2009).

Costs referring to wages and rent were chosen according to average prices paid in the area of Tripoli, the second largest city of Lebanon. This city offers a number of reasonable possible workshops as well as good connections to the main highway. Furthermore, contrarily to greater Beirut, it is mostly spared from the country´s unrests that are affecting industrial activities. Although most customers are expected to be found in the 75 km distant region of Mount Lebanon, this location is expected to provide better conditions for uninterrupted operation. Transportation of solvents resulting from this distance have been accounted in the cost estimation with 250 $ monthly for gasoline for the car.

Since entire Lebanon and the region of Tripoli are suffering from insufficient provision of electricity, a back-up generator has been incorporated into investment costs. It is expected that 250 $ monthly are needed for running this generator and thus to overcome governmental electricity black outs.

The illustrated turnover has been calculated based on the results of the quantification of solvents used according to branches. Hence, it is to assume that the majority (80 %) of recoverable waste solvents originate from Paint Producers where a price of 0.95 $ per liter should be taken. The remaining amount (20 %) is collected from Printing

&Packaging companies where the price of received waste solvents lies at 1.2 $ per liter. According to this share, an average price of 1 $ per liter has been concluded.

In case of improper storage, e.g., solvents could have evaporated to a high share and the actually received material thus might contain mostly waste ink that eventually needs to be disposed. To protect the solvent recycler, hence charging is according to received amount of waste and not for recovered material. This is further described in detail in chapter 5.6, the "design of solvent recycling service".

The monthly capacity of the utilized distillation unit lies at 19,200 l. This is composed out of the hourly capacity of 50 l and the assumption that the unit is running 4 days a week, 24 hours a day. One day per week is allocated for cleaning actions that might be necessary for job changes between the different solvents. However, the calculations do not incorporate possible additional income from selling residues as low-quality inks or paints.

Table 22 describes the development of costs and profits per liter received waste solvents while respecting different rates of utilization of the theoretical capacity within the first 12 months. However, the performed calculations acknowledge that utilized capacities might be low short after the establishment of the recycling service, since the number of accessed customers might be low. Hence, it is assumed that at time of establishment 10 % of the capacity can be made use off. However, it is expected that within this first year that many customers can be acquired, that production can be raised to 30 %.

Table 22: Development of Costs and Profits per Liter Received Waste Solvents Related to Utilization of Capacity within the First 12 Months

Utilization of Capacity	**Months 1-3 10 %**	**Months 4-6 20 %**	**Months 7-9 30 %**	**Months 10-12 30 %**
Produced liters	5,760	11,520	17,280	17,280
Depreciation [$]	771	771	771	771
Labor [$]	7,500	7,500	7,500	7,500
Financing Costs [$]	930	890	848	806
Variable Costs [$]	3,330	3,330	3,330	3,330
Rent [$]	1,200	1,200	1,200	1,200
Costs/liter [$]	2.38	1.19	0.79	0.79
Profit/liter [$]	-1.38	-0.19	0.21	0.21
Profit [$]	-7,971	-2,171	3,631	3,631

Hence, in the first three months a deficit of 7,971 $ and in the following three months an additional deficit of 2,171 $ would be generated. However, with the production increase to 30 % profits of 3,631 $ in months 7-9 and 3,631 $ in months 10-12 can be achieved. Consequently, an overall deficit of 2,880 $ can be stated for the first year. With increased productivity per liter costs reduce significantly. Hence, the initial costs of 2.38 $ decrease to 0.79 $ per liter.

In the second year utilization of 45 %, in the third year 65 %, in the fourth year 85 %, and finally from the fifth year 100 % of capacity is expected. Thereby, as illustrated in Table 23 the costs per liter are reduced to 0.23 $. Consequently, from year five, profits of 0.77 $ per processed liter are generated.

Generated waste solvents of the study area might not be sufficient for utilizing full capacity. However, as by the year 2020 around 1,318 t of organic solvents and 9,865t of waste paint are expected to be generated yearly, the actual marked demand of solvent recovery throughout entire Lebanon might be more than 48 times greater than 100 % capacity of this single distillation unit.

As mentioned earlier, investments are covered with the help of a credit. Since the payback time of this credit is five years, financing costs due not appear on the list of costs from year six anymore.

Table 23: Development of Costs and Profits per Liter Recovered Solvents Related to Utilization of Capacity within the First 12 Years

Utilization of Capacity	Year 2 45 %	Year 3 65 %	Year 4 85 %	Year 5 100 %	Year 6 100 %	Year 7-12 100 %
Liters Recovered	103,680	149,760	195,840	230,400	230,400	230,400
Depreciation [$]	3,083	3,083	3,083	3,083	4,583	4,583
Labor [$]	30,000	30,000	30,000	30,000	30,000	30,000
Financing Costs [$]	2,790	2,060	1,286	464	0	0
Variable Costs [$]	13,320	13,320	13,320	13,320	13,320	13,320
Rent [$]	4,800	4,800	4,800	4,800	4,800	4,800
Costs/liter [$]	0.52	0.35	0.27	0.22	0.22	0.23
Profit/liter [$]	0.48	0.65	0.73	0.78	0.78	0.77

The complete cost/benefit analysis for the proposed company is illustrated in Table 24. It respects the increasing utilized plant capacity and includes tax payments of 16 % of the profits. Repayment of the drawn credit stays constant over five years, while occurring financing costs of the latter decrease during the same period. The depicted financing costs have been calculated by using the tool on http://www.zinsen-berechnen.de/kreditrechner.php.

Net profit plus depreciation is indicated as positive from year one. With an increased utilization of 45 % of capacity the dividend raises to 30,204 $ by year two. In year six, utilization of capacity reaches 100 % and the credit is redeemed. Thus, a dividend of 153,848 $ is achieved.

Table 24: Computation of Cash Flow, while Respecting Varying Utilization of Capacity for the First 12 Years

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7-12
Utilization of Capacity [%]		45	65	85	100	100	100
Depreciation Costs	3,083	3,083	3,083	3,083	3,083	3,083	4,583
Labor	30,000	30,000	30,000	30,000	30,000	30,000	30,000
Financing Costs [a]	3,477	2,790	2,060	1,286	464	0	0
Variable Costs	13,320	13,320	13,320	13,320	13,320	13,320	13,320
Rent	4,800	4,800	4,800	4,800	4,800	4,800	4,800
Profit Before Taxes	-2,880[b]	49,687	96,497	143,351	178,733	179,197	177,697
Taxes (16%)	0	7,950	15,440	22,936	28,597	28,672	28,432
Profit after Taxes	-2,880	41,737	81,057	120,415	150,136	150,525	149,265
Cash Flow (net profit + Depreciation)	203	44,820	84,140	123,498	153,219	153,608	153,848
Credit	63,000						
Repayment Credit	14,616	14,616	14,616	14,616	14,616	0	0
Dividend [$]	48,587	30,204	69,524	108,882	138,603	153,608	153,848

a: interest rate calculated with http://www.zinsen-berechnen.de/kreditrechner.php.
b: resulting for first year from Table 22

The life time of the first used car is 6 years. After this time, a bigger car is bought for 15,000 $. It is used as well and its life time thereby also 6 years. The life time of the distillation unit is 12 years. The value of the car and the distillation unit equals zero after this period.

Table 25 illustrates the Development of benefits respecting an annual discount factor of 6 %. It reveals, that after a period of 12 years a net present value of 1,603,189 $ and a benefits/costs ratio of 2.18 is achieved. Year one incorporates in total expenditures the investment and in total revenue the positive amount of the credit. In year seven expenditures experience a peak, since the car is replaced by a newer one.

Table 25: Net Present Value and Cost/Benefit Ratio

Year	Total Expenditures	Total Revenue	Total Surplus	Discount factor 6%	Present Value of Expenditures	Present Value Revenue	Present Value of Surplus
1	102678	114840	12162	1,00	102.678	114.840	12162
2	73476	103680	30204	0,94	69.067	97.459	28392
3	80236	149760	69524	0,89	71.410	133.286	61876
4	86958	195840	108882	0,84	73.045	164.506	91461
5	91797	230400	138603	0,79	72.520	182.016	109496
6	76792	230400	153608	0,75	57.594	172.800	115206
7	91552	230400	138848	0,7	64.086	161.280	97194
8	76552	230400	153848	0,67	51.290	154.368	103078
9	76552	230400	153848	0,63	48.228	145.152	96924
10	76552	230400	153848	0,59	45.166	135.936	90770
11	76552	230400	153848	0,56	42.869	129.024	86155
12	76552	230400	153848	0,5	38.276	115.200	76924

B/C ratio:	2,18			**Total**	736.229	1.705.867	969.639

6. Conclusion and Recommendations

The NEK Watershed, as entire Lebanon, is facing the delicate situation that no proper industrial waste disposal is in force. Consequently, all solid and liquid wastes, hazardous and non-hazardous, follow the path of domestic waste. A great share of liquid waste is disposed to soil or sewers. Discharged materials to sewers, is eventually conveyed to river beds or directly to the Mediterranean Sea. Currently, no alternative to this final destination in form of treatment plants is available in the region. Solvents that are disposed of to the soil find a highly karstic environment that offers very low resistance and thereby retention time. Hence, contaminants could infiltrate quickly, percolate further into groundwater, or end up in the Mediterranean Sea.

In addition to polluting raw waters, contaminants could further affect the supply network of potable water as damaged and leaking pipes are normality throughout the studied watershed. At many spots leakage rates are actually that high that water finds its way through the asphalt of streets. Additionally, the network for potable water is not always pressurized. Consequently, with dropping pressure within the pipe, particles from the pipe´s environment can be sucked in. In case that these particles are hazardous contaminants, consumers are not protected towards this material but directly exposed to them. The hazardous potentials of solvents used at the local SUIs are illustrated in chapter3.2 in Table 12, Table 13, and Table 14. The most adverse chronic health impacts include damages to kidneys and liver, blood diseases, including anemia and leukemia, and generally raising risks of cancer. In addition, released solvents can affect the central nerve system, reduce fertility and pose a risk of harming unborn life.

Significant industrial growth is forecasted throughout entire Lebanon. However, due to space limitation, the industrial zone of Zouk Mosbeh cannot host any further companies. Therefore, in the course of progressing industrial development new enterprises are expected to be established in the neighboring municipalities. However, in case of intense industrial development in the municipalities of Jeita and Shaile adverse environmental degradation could occur, as well as human health could be directly at risk if no proper waste mitigation measures are taken. As the named municipalities are located within the water catchment area that feeds the Jeita Spring and the Qachqouch Spring water quality of these springs that serve as main sources of potable water for greater Beirut could become affected. Fresh water abstracted from these springs undergoes only minor treatment and is than directly conveyed to its recipients. Consequently, any contaminant reaching these water bodies is a potential threat to human health.

The investigated industrial branches of Printing& Packaging, Paint Producers, Smaller Printing Presses, Car Paint Shops, and Dry Cleaners generate high amounts of used solvents and waste ink. Many of these materials can have adverse impacts once released to the soil on environment and human health. However, those with less expected direct negative impact, still lower water quality significantly by e.g. lowering the level of dissolved oxygen in the water.

Improper waste disposal inevitably is accompanied by costs of degradation for society expressed in factors like diseases, loss of quality of nature, and eventual costs for clean ups.

The discussed industries are expected to grow significantly within the coming years. Consequently, without mitigation waste generation would increase proportionally.

Therefore, for preventing further negative impacts on human health and environment strategies for cleaner production must be introduced.

Since classical policy instruments for environmental management are ineffective in a weak Lebanese state environmental projects offering incentives and respecting interests of individual companies are most promising and possibly are running on a long term. In this context, solvent recycling (SR) has been introduced following the concept of "Cleaner Production" (CP). Accordingly, the sustainable use of resources, the raise of production efficiency, and an income increase shall be promoted. The technology transfer of SR poses a win-win situation for industries and environment, since interests of individual companies are respected while negative environmental impacts are mitigated. Hence, CP can be categorized as a policy instrument utilizing incentives through technology transfer that acknowledges and supports interests of individual companies. Correspondently, benefits arising from SR for the Lebanese government and environment have been elaborated. Thereby, the reduction of costs of degradation and social costs and the compliance to requirements of international trade agreements have been identified.

Accordingly, benefits of SR must be promoted among targeted companies. Awareness should be raised and the advantages of SR for companies should be highlighted in the points of: better reputation, monetary savings and lower impacts on environment.

For assessing the readiness of industries in the study area towards such environmentally sound technology (EST) as the introduced method of SR a questionnaire has been conducted. The results of the conducted questionnaire clearly state a positive overall response. It further identifies that companies of same branches use same solvents. This eases the management of a possible recycling service significantly and furthermore

enhances cost efficient performance. The results further showed that so far no explicit recycling service is existent and only minor on-spot SR and re-use is performed. Negative expectations regarding solvent recycling are very limited and only refer to possible quality losses of the recovered product.

Based on the questionnaire´s results and discussions with external experts a monthly amount of 12,515 l of used solvents could be estimated for the known SUIs within the study area. However, since probably not all branches of SUIs within the NEK Watershed have been considered, the actual volume of used solvents might be even higher. However, projecting the total monthly quantity for the entire year an amount of approximately 150.2 t of used solvents that is potentially threatening the environment would result. Taking into consideration that Zouk Mosbeh has a significant share of the country´s total industrial zone and that the total estimated quantity for the entire country lays at around 940 t/year (El-Fadel, Zeinati, El-Jisr, & Jamali, 2001a) the projected number appears very realistic.

However, each company follows a slightly different strategy of disposing its waste. Some rely on disposal aside domestic waste, where the material might be transported out of the NEK basin disposed of at landfills, while others discharge their effluents directly to sewers and soil. Moreover, eventually not all questioned companies stated the procedure of waste disposal truthfully. Consequently one cannot conclude from the estimated quantity the amount of used solvents actually affecting the NEK Watershed´s environment negatively. However, if only a fraction of the estimated amount reaches the water bodies severe effects on human health, wildlife, and water quality must be expected.

In the context of the results of the questionnaire the verification of hypothesis 1, "***Solvents are dumped after use"*** and hypothesis 2, ***"With adequate economic incentive industries are willing to recycle used solvents. Be it by implementing of on-site solvent recycling or participating in an outsourced recycling program"*** can be stated. Used solvents are dumped by all questioned parties but one. Furthermore validating hypothesis 2, the most convincing aspect of solvent recycling appears to be of monetary nature as stated by companies. Thereto, all respondents but one expressed their willingness to collect their used solvents and making it thereby available for recycling. Correspondently, a significant number of companies are interested in having their own recycling unit. Moreover, the vast majority of questioned companies are willing to participate in an external recycling service. Aside monetary benefits the argument of working more environmental friendly was a further supporting advantage named by questioned parties.

Although some companies expressed their interest in acquiring a distillation unit, the introduction of an external recycling service rather than on-spot recycling is recommended. This should ensure correct handling of occurring residues from the distillation process of recycling. Accordingly, the service should be performed by a trust worthy company that is working under to international environmental standards. This company should be supported with information and advice in terms of waste disposal by institutions like the Industrial Research Institute (IRI), Council for Development and Reconstruction (CDR), Ministry of Economy (MoE), Lebanese Cleaner Production Center (LCPC) and the German Agency for Development Cooperation (GTZ).

However, when applying the proposed recycling method of vacuum distillation, the majority of generated residues can be re-used as ink/paint. Consequently, recycling of

up to 100 % is possible in many cases. Hence, only marginal quantities of wastes that require disposing are expected. In this manner, environmentally sound performance is further enhanced even without proper industrial waste facilities for possible disposal. Residues from solvent recycling originating from dry cleaners can be forwarded to crude oil processing companies.

Correspondently to the positive response to the questionnaire, a service scheme for a recycling company has been established. To ease handling of used solvents container size for collection is recommended to be limited to 30 l, since this is believed to be the maximum weight a worker can lift by hand.

In this course, a business plan for a recycling service company has been developed that depicts the profitability of such recycling service. For financing purposes a credit of 63,000 $ with a calculatory interest rate of 6 % and a payback time of five years has been assumed. The total monthly capacity of the installed unit lies at 19,200 l. However, the breakeven point is reached at a capacity utilization of 23.25 %, accordingly 4,464 l.

Although the high amount of about 12,515 l of used solvents monthly have been estimated as available in the NEK Watershed, it must be assumed that only a fraction of it will be assessable for the recycling service in the first time period of its establishment.

Consequently, to ensure economically feasible operation of the recycling service, area of addressed companies should be broadened to entire Lebanon, especially to greater Beirut, since most of the targeted industries are located there.

This area extension should be further supported with information and contacts by institutions like Association of Lebanese Industrialists (ALI), Chamber of Industry and Commerce (CCI), and further related associations.

Annex

I. Discharges from Paint Producer at Different Days in approx. Distance of 500 m to Mediterranean Sea



II. Accounted Companies of the Kessrwan Governorate

Company	Business	Approached
La Primiera 2	Dry Cleaner	Yes
Clean Plus	Dry Cleaner	Yes
Nazih Safi	Dry Cleaner	Yes
Yousef Nassar	Car Paint Shop	Yes
Antoine Alwan	Car Paint Shop	No
Hermal Chahine	Car Paint Shop	No
Wissam Zgheib	Car Paint Shop	No
Philipe Haddad	Car Paint Shop	No
Hani Aziz	Car Paint Shop	No
Georges Andraos	Car Paint Shop	No
Anvers	Car Paint Shop	Yes
CCM	Paint Producer	No
General Paint	Paint Producer	Yes
The Sons of M. Boutros Co.	Paint Producer	Yes
Happy Wall	Paint Producer	Yes
Boulos Kozah Co.	Paint Producer	No
Noula	Paint Producer	Yes
Antoine Hakmeh	Paint Producer	No
Ebf	Printing	Yes
Color Printing Press	Printing	Yes
Nabil Radi	Printing	No
MicroGraph	Printing	Yes
Mediapap	Printing & Packaging	Yes
Masterpak	Printing & Packaging	Yes
HOREPA	Printing & Packaging	Yes
Bag-it SAL	Printing & Packaging	No
Luna Press	Printing & Packaging	Yes
Pack Plus	Printing & Packaging	No
Middle East Co. For Trading And Packaging -Meptico	Printing & Packaging	No
United Printing CO.	Printing & Packaging	No
PakPlast s.a.r.l	Printing & Packaging	No
Rolls & Bags S.A.R.L.	Printing & Packaging	No

III. LIBNOR Standards for Potable Water

Characteristics	Maximum Limit allowed (mg/L)	Characteristics	Maximum Limit allowed (mg/l)
Chlorine (Cl2)	0.3	Arsenic (As)	0.05
Aluminium (Al)	0.2	2(2.4.5) Thrichlorophenoxy propionic acid	0.009
Potassium (K)	12	2.4 dichlorophenoxy acetic acid	0.03
Sodium (Na)	150	Toxaphene	0.003
Nitrate (NO3)	45	Methoxy Chlor	0.02
Hydrogen Sulfide (H2S)	0.05	Lindane	0.0002
Nitrite (NO2)	0.05	Aldrin + Dieldrin	0.00002
Organics	0.5	Chloroform	0.1
Phosphate (P2O5)	1	Halogenic Organic Cpds	0.06
Ammonia	0	Fluoride	
Alkali-Benzene	0	between 8°C & 12°C	1.5
Chloroform residues	0.2	between 25°C & 30°C	0.7
Mineral oils	0	Aromatic Hydrocarbons with:	
Phenol Cpds	0.001	1.12 Benzoperylene	0.0002
Hardness (Ca)	250	3.4 Benzopyrene	0.00001
Chlorides(Cl-)	200	11.12 Benzofluoranthene	0.0001
Calcium Carbonate (CaCO3)	200	3.4 Benzofluoranthene	0.0002
Zinc (Zn)	5	Fluoranthene	0.0002
Sulfates (SO4)	250	(Ni)	0.02
Manganese (Mn)	0.05	Silver (Ag)	0.01
Magnesium (Mg)	50	Barium (Ba)	0.5
Iron (Fe)	0.3	Chromium (Cr)	0.05
Copper (Cu)	1	Lead (Pb)	0.01
Total dissolved solids	500	Selenium (Se)	0.01
pH value	6.5-8.5	Mercury (Hg)	0.001
		Cyanide (CN)	0.05
		Cadmium (Cd)	0.005

IV. Questionnaire Sheet

INTEGRATED WATER RESOURCES MANAGEMENT
MASTER OF SCIENCE FOR ARAB AND GERMAN YOUNG PROFESSIONALS IWRM

Date, Place: ______________________________

Company Name: ______________________________

Year of Establishment: ____________ **Products:** ______________________

Number of Employees: ______________________________

1. From which materials are your products made off?	
2. What kind of solvents do you use?	
3. How many liters of solvents do you use for cleaning purposes per month? (And which)	
4. What are your costs for cleaning-solvents per month?	
5. What are the costs of one container cleaning-solvent?	
6. How many liters are in container of cleaning-solvent?	
7. What do you do with the used cleaning-solvent?	
8. Do you face problems in purchasing the required solvents?	Yes ( ) No ( )
9. Do you have the possibility of controlled disposal of the used solvent?	Yes ( ) No ( )
10. If yes, who is it taking and how is it organized?	

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11. Do you think that environmental friendly production causes extra costs?	Yes ( ) No ( )
12. Are you interested in reducing costs for cleaning-solvents?	Yes ( ) No ( )
13. Do you know what recycling means?	Yes ( ) No ( )
14. If you can reduce your costs for solvent recycling, would you be willing to collect your used solvent? **If "No", continue with 18.**	Yes ( ) No ( )
15. Would you be interested in having your own recycling machine?	Yes ( ) No ( )
16. Would you be interested in a recycling service?	Yes ( ) No ( )
17. What other advantages than monetary can you imagine from recycling?	
18. What disadvantages could you imagine?	
If 12. = No, answer following question: What are your major constraints in participating?	
19. Are you aware of impacts on environment by discharging used solvent?	Yes ( ) No ( )
20. If Yes: What impacts can you imagine?	

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اليوم....................   المكان...

اسم الشركة...

متى تأسست الشركة.. المنتج..

عدد الموظفين...

1- ما هي المواد التي تستخدم في صناعة منتجكم؟	
2- ما هي المواد الكيميائية التي تسخدم في تنظيف الالات؟	
3- كم عدد اللترات اللتي تستخدم في التنظيف خلال الشهر الواحد؟	
4- ما هي التكلفة التي يتم دفعها لمواد التنظيف خلال الشهر الواحد؟	
5- ما هي تكلفة البرميل الواحد من مواد التنظيف؟	
6- كم عدد اللترات التي توجد في البرميل الواحد؟	
7- كيف يتم التخلص من مواد التنظيف بعد الإنتهاء من استعمالها؟	
8- هل تواجه مشاكل في شراءالمواد الكيميائية للتنظيف؟	نعم( ) لا( )

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9- هل تتم السيطرة الرسمية على إتلاف المواد الكيميائية للتنظيف؟	نعم( ) لا( )
10- إذا كان الجواب نعم، ما هي الجهة المسؤولة و كيف تتم السيطرة؟	
11- هل تعتقد ان ان المنتجات الصديقة للبيئة لها تكلفة عالية؟	نعم( ) لا( )
12- هل أنت مهتم بتقليل التكلفة التي تدفعها لمواد التنظيف؟	نعم( ) لا( )
13- هل لديك أي فكرة عن إعادة التدوير؟	نعم( ) لا( )
14- إذا كان هناك إمكانية لتقليل تكلفة المواد الكيميائية للتنظيف، هل أنت مستعد لجمع هذه المواد بعد استخدامها؟إذا كان الجواب لا أكمل مع الفرع 18	نعم( ) لا( )
15- هل أنت مهتم ليكون عندك الة خاصة بك لإعادة التدوير؟	نعم( ) لا( )
16- هل انت مهتم بخدمات إعادة التدوير؟	نعم( ) لا( )
17- هل تعتقد وجود فوائد أخرى لإعادة التدوير غير تقليل التكلفة؟	نعم( ) لا( )
18- من وجهة نظرك ما هي السلبيات التي تعتقد وجودها من إعادة التدوير؟	
إذا كان جواب فرع 12 لا ما هي العوائق التي قد تواجهك أو تمنعك من إعادة التدوير؟	
19- هل عندك فكرة عن الأضرار التي تسببها إتلاف المواد الكيميائية للبيئه؟	نعم( ) لا( )
20- إذا كان الجواب نعم , ما هي التأثيرات السلبية من وجهة نظرك؟	

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V. Gathered Answeres to distributed Questionnaire

Place	Year of Establishment	Products	No. of Employees	1	2	3
Ballouneh	1990	Advanced Car Painting	5	Car Painting	Thinner	40 l
Zouk Mosbeh	1978	Car Painting	30	Car Painting	Thinner	200 L
Ballouneh	1995	Car Painting	1	Car Painting	Thinner	60 l
Zouk Mosbeh	1972	Dry Cleaner	15	Cleaned Cloths	Perchloricethylene	None, 50 l
Zouk Mosbeh	1985	Dry Cleaner	25	Cleaned Cloths		
Jeita	1985	Dry Cleaner	1	Cleaned Cloths	Perchloricethylene	10 l
Zouk Mosbeh	1985	Paint	45	Paint	MEK, Toluen, Xelene	500 l
Zouk Mosbeh		Paint	30	Paint	Water	
Zouk Mosbeh	1990	Paint	39	Paint	MEK, Toluen, Xelene	None
Zouk Mosbeh	1998	Paint	15	Paint	Thinner	1200 l
Zouk Mosbeh	1995	Printing	5	Packaging	Water, Benzin	30 l
Zouk Mosbeh	1980	Printing	25	Packaging	Benzin, Ipa	50 l, 15 l
		Printing & Packaging		Packaging		
Zouk Mosbeh	1974	Printing & Packaging	30	Packaging	Isopropanol	150 l
Zouk Mosbeh	1967	Printing & Packaging	45	Carton Board	Isopropanol	100 l
Zouk Mosbeh	1992	Furniture	20	Wood, Paint, Applications	Thinner	25 l

4	5	6	7	8	9	10	11	12
80 $	40 $	20 l	Re-Use for underside painting of car	No	No	XXX	No	Yes
250 $	250$	200 l	give back used material to provider (for free)	No	Yes	giving back	No	Yes
150 $	30 $	12/13 l	dispose to ground, grass	No	No	XXX	No	Yes
250 $	5$/l		residue like power, disposed with Sukleen					
50 $			Garbage	No	No	XXX	No	Yes
800 $			Re-use, give to people	No	No	XXX	Yes	Yes
375 $			Recycling with own machine	No	No	XXX	No	Yes
30 $			disposing with Sukleen					
90 $			dispose with sukleen	No	No	XXX	No	Yes
375 $			storing for recycling	No	No	XXX	Yes	Yes
250 $			Garbage	No	No	XXX	Yes	Yes
40 $	245 $	200 l	disposing with Sukleen	No	No	XXX	Yes	Yes

13	14	15	16	17	18	If 12	19	20
Yes	XXX	XXX	Yes (purchasing)	XXX	XXX	XXX	Yes	Trees dying, bad smell
Yes	Yes	No	Yes	stop throwing thinner to the sea	None	XXX	No	more harmful for health than for environment
Yes	Yes	No	Yes	stop disposal	quality	XXX	No	No effect, like water
			Yes (purchasing)				yes	harmful for water
Yes	Yes	No	Yes	XXX	None	XXX	Yes	harmful for nature
Yes	Yes	Yes	No	environmental friendly	None	XXX	Yes	Soil degradation by infiltration
			Yes (purchasing)					harmful, waste of money
Yes	Yes	Yes	Yes	better for env.	XXX	XXX	Yes	Harmful
Yes	Yes	No	Yes	XXX	None	XXX	Yes	health
Yes	Yes	Yes	Yes	cleaner production	None	XXX	Yes	harmful
Yes	Yes	Yes	Yes	be environmental frriendly	None	XXX	Yes	harmful, waste of money
Yes	No				quality constraints	No time for collecting solvents	Yes	harming environment

Declaration of Authoriship

I, Christine Batsch, hereby declare that this thesis "Towards the Prevention of Water Pollution from Industrial Activities in the Nahr El-Kalb Watershed" is entirely the result of my own work except where otherwise indicated. This thesis is not used as part of any other examination and has not yet been published.

Signature

Place, Date

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منع تلوث المياه من النشاطات الصناعية في حوض نهر الكلب، لبنان
التدوير من أجل إنتاج أنظف في الصناعات التي تستخدم المذيبات

اعداد

كريستينا باتش

المشرف

الدكتور عباس العمري

المشرف المشارك

الدكتوره سابينه شلوتر

الملخص

لقد أدت عودة الاستقرار السياسي النسبي في لبنان إلى إنتعاش الصناعة مما نتج عنه إزدهار الكثير من الصناعات ومن ضمنها الصناعات التي تستخدم المذيبات ولكن لم يرافق هذا الإزدهار الصناعي طرق لإدارة المخلفات التي تنتجها هذه الصناعات. تهدف هذه الرسالة إلى دراسة الملوثات الناتجة عن الصناعات التي تستخدم المذيبات للحد من اثارها البيئية مثل تلوث مصادر المياه في حوض نهر الكلب. إن المذيبات المستهلكة حاليا يتم التخلص منها بطرق غير صحيحة تؤدي إلى تلوث البيئة بما فيها مصادر المياه بالإضافة إلى تلوث البحر المتوسط. إن صناعات الطباعة والتغليف والمطابع الصغيرة ومصانع الدهان وورش دهان السيارات وورش التنظيف الجاف هي أهم الصناعات المنتشرة في منطقة سوق مصبح ضمن منطقة الدراسة والتي تستخدم المذيبات.

لتحقيق الهدف من هذه الدراسة تم التعرف على ما تخلفه الصناعات الموجودة في منطقة الدراسة من مذيبات. ومن ثم تم إقتراح التدوير لإعادة الإستخدام من أجل بيئة أنظف. إن نشر تكنولوجيا إعادة التدوير تحقق مصلحة أصحاب الصناعات وتحمي البيئة في نفس الوقت. ومن أجل تقييم رغبة وقابلية أصحاب الصناعات لإعادة التدوير تم عمل إستبيان لهذه الغاية حيث بينت النتائج أن الغالبية العظمى من أصحاب الصناعات راغبون في إعادة التدوير.

إن كمية المذيبات المستهلكة شهريا تم تقديرها بحوالي 12515 لترا. كما تبين لاحقا أن الصناعات المتشابهة تستخدم نفس المذيبات. كما أنه من المحتمل أن كمية المذيبات المستهلكة أكبر من الكمية التي تم تقديرها حيث أنه من المحتمل أن بعض الصناعات في منطقة الدراسة لم يتم إحتسابها.
إعتمادا على الاراء الايجابية بخصوص التدوير وإعادة الإستخدام فقد تم تطوير خطة للتدوير.كما تم التعرف على فوائد وميزات إعادة التدوير لكل من أصحاب الصناعة والحكومة والبيئة. وقد تم تطويرمخطط عمل يبين الجدوى الإقتصادية لإعادة التدوير.